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U. S. DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

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MONTHLY WEATHER REVIEW

VOLUME 45, No. 4

APRIL, 1917

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NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for the illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Editor.

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W. B. NO. 616.

APRIL, 1917.

CLOSED JUNE 2, 1917
ISSUED JUNE 30, 1917

INTRODUCTION.

As explained in this introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS TO THE MONTHLY WEATHER REVIEW are published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Beginning August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observations by Weather Bureau observers and others as reported to the Washington office.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1915. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but *all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.*

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but collected and published by States at selected section centers.

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belén College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

CORRIGENDA.

REVIEW, March, 1917:
Page 135, col. 2. 12th entry, *for* "Merrill, Geo. P." *read* "McAdie, Alex. G."
22d entry, *for* "fulmizaioni" *read* "fulminazioni."

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SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASUREMENTS DURING APRIL, 1917.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., May 25, 1917.]

For a description of instrumental exposures and an account of the methods of obtaining and reducing the measurements the reader is referred to the REVIEW for January, 1917, **45**:2.

The monthly means and departures from normal values in Table 1 show that during April, 1917, direct solar radiation averaged below normal intensity at Washington, D. C., and Santa Fe, N. Mex., slightly above normal at Madison, Wis., and very close to normal at Lincoln, Nebr. There were comparatively few clear days at any of the stations, and the series obtained at Madison on the afternoon of the 6th and the morning of the 13th are the only two that are good enough to permit of extrapolation to zero air mass. These two series give 1.96 and 1.81, respectively, for the value of the solar constant.

Table 3 shows only unimportant departures from normal radiation at Washington, a deficiency of nearly 8 per cent at Madison, and of 20 per cent at Lincoln.

Skylight polarization measurements at Washington give a mean of 56 per cent, with a maximum of 66 per cent on April 10; and at Madison, a mean of 57 per cent, with a maximum of 67 per cent on the 13th. These are very close to average values for April.

TABLE 1.—*Solar radiation intensities during April, 1917.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 4	.....	1.21	1.12	.....	.....	.....	.....	.....	.....	.....
7	1.35	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	.....	1.44	1.26	.....	.....	.....	.....	.....	.....	.....
10	1.40	1.19	1.17	0.86	0.78	0.72	0.68	0.63	0.57	.....
11	.....	1.02	0.83	0.71	0.63	0.55	.....	.....	.....	.....
14	.....	.....	0.97	0.88	.....	.....	.....	.....	.....	.....
16	.....	1.10	.....	.....	.....	0.88	.....	.....	.....	.....
17	.....	0.92	0.81	0.67	0.53	.....	.....	.....	.....	.....
23	1.24	1.13	1.00	0.88	0.78	0.72	0.57	.....	.....	.....
27	.....	0.99	.....	.....	.....	.....	.....	.....	.....	.....
30	.....	1.00	0.86	0.72	0.58	0.51	0.46	0.41	0.38	.....
Monthly means	**1.33**	**1.11**	**1.00**	**0.79**	**0.66**	**0.68**	**0.57**	**(0.52)**	**(0.48)**	.....
Departure from 9-year normal	**−0.04**	**−0.05**	**−0.05**	**−0.15**	**−0.20**	**−0.12**	**−0.14**	**−0.19**	**−0.19**	.....
P. M.										
Apr. 3	.....	1.41	1.27	.....	.....	.....	.....	.....	.....	.....
10	.....	1.20	0.79	0.66	0.56	0.48	.....	0.37	0.35	.....
Monthly means	.....	**(1.30)**	**(1.03)**	**(0.66)**	**(0.56)**	**(0.48)**	.....	**(0.37)**	**(0.35)**	.....
Departure from 9-year normal	.....	**+0.22**	**+0.03**	**−0.23**	**−0.27**	**−0.21**	.....	**−0.13**	.....	.....

TABLE 1.—*Solar radiation intensities during April, 1917*—Continued.

Madison, Wis.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 2	1.57	1.45	.....	.....	.....	.....	.....	.....	.....	.....
6	1.55	1.44	1.37	1.28	1.19	1.15	1.11	.....	.....	.....
9	.....	1.35	.....	.....	.....	.....	.....	.....	.....	.....
12	.....	.....	1.16	1.07	0.92	.....	.....	.....	.....	.....
13	1.51	1.42	1.34	1.25	.....	.....	.....	.....	.....	.....
21	1.35	1.19	1.15	1.11	1.03	0.96	0.89	.....	.....	.....
Monthly means	**1.50**	**1.37**	**1.26**	**1.18**	**1.05**	**(1.06)**	**(1.00)**	.....	.....	.....
Departure from 7-year normal	**+0.12**	**+0.04**	**+0.04**	**+0.05**	**−0.05**	**−0.04**	**−0.04**	.....	.....	.....
P. M.										
Apr. 6	.....	1.43	1.33	1.23	1.14	.....	.....	.....	.....	.....
13	.....	1.40	.....	.....	.....	.....	.....	.....	.....	.....
21	.....	1.19	.....	.....	.....	.....	.....	.....	.....	.....
Monthly means	.....	**1.34**	**(1.33)**	**(1.23)**	**(1.14)**	.....	.....	.....	.....	.....
Departure from 7-year normal	.....	**+0.06**	**+0.11**	**+0.10**	**+0.04**	.....	.....	.....	.....	.....

Lincoln, Nebr.

A. M.										
Apr. 8	1.62	1.46	1.31	1.20	1.07	1.00	0.95	0.89	0.81	.....
9	1.61	1.46	1.32	1.20	1.08	1.00	0.95	0.86	0.76	.....
21	.....	1.38	1.16	1.12	0.93	0.80	0.71	0.65	0.60	.....
Monthly means	**(1.62)**	**1.43**	**1.26**	**1.17**	**1.03**	**0.93**	**0.87**	**0.80**	**0.72**	.....
Departure from 2-year normal	**+0.07**	**+0.02**	**±0.00**	**+0.02**	**−0.02**	**−0.03**	**±0.00**	**−0.05**	**±0.00**	.....
P. M.										
Apr. 18	.....	.....	1.01	0.87	0.79	0.67	.....	.....	.....	.....
Monthly means	.....	.....	**(1.01)**	**(0.87)**	**(0.79)**	**(0.67)**	.....	.....	.....	.....
Departure from 2-year normal	.....	.....	**−0.11**	**−0.14**	**−0.14**	**−0.18**	.....	.....	.....	.....

Santa Fe, N. Mex.

A. M.										
Apr. 6	.....	1.41	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	1.41	.....	.....	.....	.....	.....	.....	.....
20	1.48	1.47	1.36	.....	1.24	1.16	1.13	1.10	1.04	.....
21	1.43	1.37	1.29	1.24	1.20	1.15	1.10	1.05	0.99	.....
23	.....	1.34	1.29	.....	.....	1.11	1.06	1.05	.....	.....
24	1.41	.....	1.26	1.22	1.20	1.15	1.09	1.02	.....	.....
25	.....	.....	1.20	1.11	1.03	0.97	0.92	0.87	0.82	0.77
26	.....	.....	.....	.....	1.15	1.10	1.07	.....	.....	.....
30	1.44	.....	.....	.....	.....	.....	.....	.....	.....	.....
Monthly means	**1.44**	**1.40**	**1.30**	**1.19**	**1.16**	**1.11**	**1.06**	**1.02**	**0.95**	**(0.77)**
Departure from 5-year normal	**−0.09**	**−0.03**	**−0.11**	**−0.06**	**−0.04**	**−0.04**	**−0.04**	**−0.02**	**−0.02**	.....
P. M.										
Apr. 20	.....	1.27	1.16	1.08	1.00	0.93	.....	.....	.....	.....
21	.....	.....	1.09	1.02	0.95	.....	.....	.....	.....	.....
25	.....	1.18	1.06	.....	.....	.....	.....	.....	.....	.....
30	.....	1.18	1.05	0.98	0.93	.....	.....	.....	.....	.....
Monthly means	.....	**1.21**	**1.09**	**1.03**	**0.96**	**(0.93)**	.....	.....	.....	.....

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	A. M.	P. M.	Dates.	A. M.	P. M.	Dates.	A. M.	P. M.	Dates.	A. M.	P. M.
1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*	1917.	*mm.*	*mm.*
Apr. 3	4.17	2.62	Apr. 2	2.74	3.00	Apr. 8	3.15	3.63	Apr. 6	2.26	1.96
4	4.57	4.75	6	2.62	2.87	9	3.45	4.57	7	1.52	1.52
7	4.37	3.30	9	2.74	5.36	18	7.29	10.21	20	2.36	1.60
9	3.30	2.36	12	4.37	3.63	21	5.16	5.16	21	3.00	1.19
10	2.16	2.74	13	1.68	3.30	.....	.....	.....	23	1.78	2.62
11	2.06	3.99	21	4.75	6.02	.....	.....	.....	24	2.74	1.96
14	2.87	3.30	.....	.....	.....	.....	.....	.....	25	3.81	3.99
16	3.45	4.37	.....	.....	.....	.....	.....	.....	26	3.15	2.06
17	4.57	5.16	.....	.....	.....	.....	.....	.....	30	3.81	2.16
23	9.14	9.47	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	4.57	7.29	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	9.14	9.83	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE 3.—*Daily totals and departures of solar and sky radiation during April, 1917.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
	calories.	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*	*calories.*
Apr. 1	487	77	308	100	−307	−73	100	−307	−73
2	299	535	383	−91	149	1	9	−158	−72
3	539	317	203	147	−71	−180	156	−229	−252
4	538	158	147	144	−232	−237	300	−461	−489
5	64	167	460	−332	−225	75	−32	−686	−414
6	202	595	358	−197	200	−27	−229	−486	−441
7	590	281	64	189	−116	−322	−40	−602	−763
8	280	631	551	−124	231	164	−164	−371	−599
9	596	529	522	189	126	134	25	−245	−465
10	618	513	425	208	108	36	233	−137	−429
11	589	524	336	177	116	−54	410	−21	−483
12	358	539	508	−57	128	117	353	107	−366
13	167	621	371	−251	207	−20	102	314	−386
14	598	418	493	178	1	101	280	315	−285
15	420	559	60	−3	139	−333	277	454	−618
16	606	186	249	180	−236	−144	457	218	−762
17	522	497	305	94	72	−89	551	290	−851
18	476	325	408	45	−103	13	596	187	−838
19	422	292	305	−12	−138	−90	584	49	−928
20	430	394	245	−7	−39	−151	577	10	−1,079
Decade departure.....							**344**	**147**	**−650**
21	388	601	527	−51	166	130	526	176	−949
22	587	440	509	145	2	111	671	178	−838
23	558	480	428	113	40	30	784	218	−808
24	448	562	232	1	120	−167	785	338	**−975**
25	232	104	438	−218	−340	38	567	−2	−937
26	106	392	91	−347	−64	−309	220	−66	−1,246
27	502	549	76	46	102	−325	266	36	−1,571
28	134	274	46	−324	−175	−356	−58	−139	−1,927
29	266	77	234	−195	−374	−169	−253	−513	−2,096
30	574	103	160	110	−350	−244	−143	−863	−2,340
Decade departure.....							**−720**	**−873**	**−1,261**
Excess or deficiency since first of year.. {calories.....							**−1,500**	**+675**	**−2,708**
{Per cent.....							−4.2	+1.9	−7.2

EQUATION OF HORIZONTAL RAINBOWS.[1]

[Paper read before the Tokyo Mathematico-physical Society, Jan. 20, 1917.]

By KŌKICHI OTOBE.

1. The subject of this paper was suggested to me when the horizontal rainbows were being demonstrated [*cf.* MONTHLY WEATHER REVIEW, Jan., 1917, **45**:5]. My object is:

(*a*) To deduce the general equation of the horizontal rainbows due to a source of light at a finite distance from the observer.

(*b*) To show that the curves are not in general the conic sections;

(*c*) But when the straight line passing through the source and the observer's eye is perpendicular to the plane sheet of fine water drops, the curves become concentric circles.

(*d*) To verify the general equation by deducing some special cases actually observable with parallel rays of the sun.

(*e*) To confirm the above results by experiment.

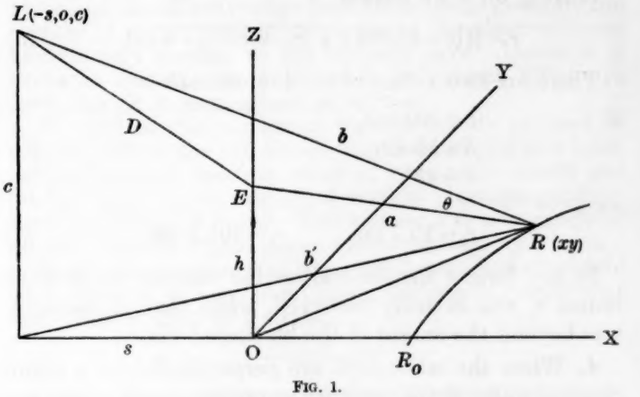

FIG. 1.

2. Let the rectangular coordinate axes be drawn as in figure 1, $(-s,0,c)$, $(0,0,h)$ and $(x,y,0)$ being the coordinates of a source of light, L, of an observer's eye E, and of a point R in the arc R_0R of the rainbow, respectively.

And let θ denote the angle between the incident ray LR and the effective ray RE.

Then we obtain from the triangle ERL,

$$D^2 = a^2 + b^2 - 2ab\cos\theta \tag{1}$$

where

$$\left.\begin{aligned} a^2 &= h^2 + r^2 \\ b^2 &= c^2 + b'^2 \\ b'^2 &= (s+x)^2 + y^2 \\ r^2 &= x^2 + y^2 \end{aligned}\right\} \tag{2}$$

Substituting (2) in (1), and remembering the relation

$$D^2 = (c-h)^2 + s^2,$$

or

$$D^2 - c^2 - h^2 - s^2 = -2ch,$$

we have

$$(ch + xs + x^2 + y^2)^2 = (h^2 + x^2 + y^2)(c^2 + s^2 + x^2 + y^2 + 2xs)\cos^2\theta, \tag{3}$$

as the required equation.

The curve is symmetrical about the axis of X, but not so simple as to be traced. Since the equation contains the angle θ and the coordinates of the eye, E, the position of the rainbow will be different as we look with the right eye or with the left. This was actually the case even with the horizontal rainbow observed on the surface of the moat.

3. When both the source of light, L, and the observer's eye, E, are in the Z axis, we may put $s=0$, so that we have from (3)

$$(ch + r^2)^2 = (c^2 + r^2)(h^2 + r^2)\cos^2\theta,$$

hence

$$\begin{aligned}(ch + r^2)^2 \sin^2\theta &= [(c^2 + r^2)(h^2 + r^2) - (ch + r^2)^2]\cos^2\theta, \\ &= (c-h)^2 r^2 \cos^2\theta,\end{aligned}$$

therefore

$$ch + r^2 = \pm(c-h)r\cot\theta.$$

The plus or minus sign should be taken according as $c>h$ or $c<h$.

[1] *Reprinted from* Jour. Meteorol. Soc. Japan, Feb., 1917, **36**: 7-14.

Suppose $c>h$ as in figure 1, then we have

$$r^2-(c-h)r\cot\theta+ch=0. \tag{4}$$

Solving for r we obtain

$$r=\tfrac{1}{2}[(c-h)\cot\theta\pm\sqrt{(c-h)\cot^2\theta-4ch}]. \tag{5}$$

There are two values of r. For example,

if $c=200$ cm,
$h=10$ cm,
$\theta=42°$,

we have

$$r_1=19.7 \text{ cm.}; \qquad r_2=191.4 \text{ cm.}$$

In my former demonstration the circular rainbow of radius r_1 was actually observed, while that of radius r_2 was beyond the extent of the blackened plate.

4. When the sun's rays are perpendicular to a plane sheet of water drops, we must suppose c tends to become infinity, while h and θ remain finite. Thus writing (5) as follows

$$r=\tfrac{1}{2}[(c-h)\cot\theta]\left[1-\sqrt{1-\frac{4ch}{(c-h)^2}\tan^2\theta}\right],$$

and expanding the expression under the radical sign, we have

$$r=\frac{ch\tan\theta}{c-h}.$$

By putting $c=\infty$, we obtain

$$r=h\tan\theta. \tag{6}$$

This might have been obtained directly from (3) by supposing r and s finite and c infinite, for then equation (3) is reduced to

$$h^2=(h^2+x^2+y^2)\cos^2\theta,$$

whence

$$x^2+y^2=h^2\tan^2\theta. \tag{7}$$

This represents a circle of radius $h\tan\theta$, being the base of a right cone having the observer's eye as the vertex and semivertical angle $=\theta$, as shown in figure 2.

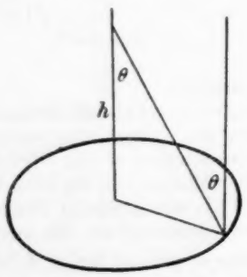

FIG. 2.

5. When the altitude of the sun is less than $\frac{\pi}{2}$, suppose c and s tend to infinity, while their ratio remains finite and equals $\tan\phi$, so that

$$c=s\tan\phi;$$

then writing (3) in the form

$$\left(x+h\tan\theta+\frac{r^2}{s}\right)^2=(h^2+r^2)\left(\sec^2\phi+\frac{2x}{s}+\frac{r^2}{s^2}\right)\cos^2\theta$$

and putting $s=-\infty$, we have

$$(x+h\tan\phi)^2=(h^2+r^2)\sec^2\phi\cos^2\theta.$$

After a few reductions we obtain

$$\begin{aligned}x^2(\cos^2\phi-\cos^2\theta)+2xh\sin\phi\cos\phi-\\ y^2\cos^2\theta+h^2(\sin^2\phi-\cos^2\theta)=0\end{aligned} \tag{8}$$

This is the equation of conic sections.

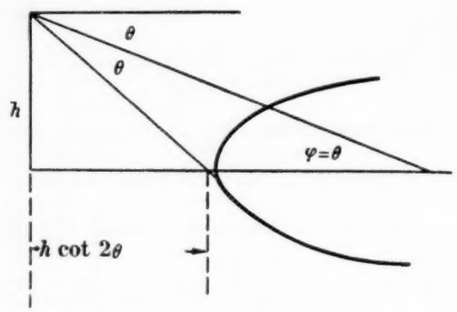

FIG. 3.

If the sun's altitude ϕ is equal to θ (see fig. 3), equation (8) becomes

$$y^2\cos^2\theta=2xh\sin\theta\cos\theta+h^2(\sin^2\theta-\cos^2\theta)$$

or

$$y^2=2h\tan\theta(x-h\cot 2\theta), \tag{9}$$

which represents a parabola having its latus rectum equal to $2h\tan\theta$ and intersecting the axis of x at a point whose distance from the origin is $h\cot 2\theta$.

6. If $\phi\neq\theta$, transforming the origin to the center (see fig. 4)

$$\begin{cases}y=0\\ x=-\dfrac{h\sin\phi\cos\phi}{\cos^2\phi-\cos^2\theta}=0,\end{cases}$$

equation (8) is reducible to

$$(\cos^2\phi-\cos^2\theta)x^2-\cos^2\theta y^2-\frac{h^2\sin^2\theta\cos^2\theta}{\cos^2\phi-\cos^2\theta}=0,$$

or

$$\frac{x^2}{\left(\dfrac{h\sin\theta\cos\theta}{\cos^2\phi-\cos^2\theta}\right)^2}-\frac{y^2}{\dfrac{(h\sin\theta)^2}{\cos^2\phi-\cos^2\theta}}=1. \tag{10}$$

If $\cos^2\phi-\cos^2\theta>0$ or $\phi<\theta$, the above equation represents a hyperbola, which is the form of horizontal rainbow most frequently observable with the morning sun, for the altitude is probably less than $\phi\doteq 42°$. (cf. fig. 4.)

If $\cos^2\phi-\cos^2\theta<0$ or $\phi>\theta$, equation (10) represents an elliptical rainbow as shown in figure 5.

7. To confirm the above results recourse must be had to the following experiment. One end, E, of the glass rod supported horizontally on an adjustable vertical stand, is used to specify the position of the observer's eye. And E', the shadow of E, is marked on the blackened plate. As EE', ER, RE' and EP (the height of E above the plate) are directly measurable, the angles ϕ and θ can be easily calculated. The calculated value of θ is found to be nearly equal to that given by the exact theory of Airy.

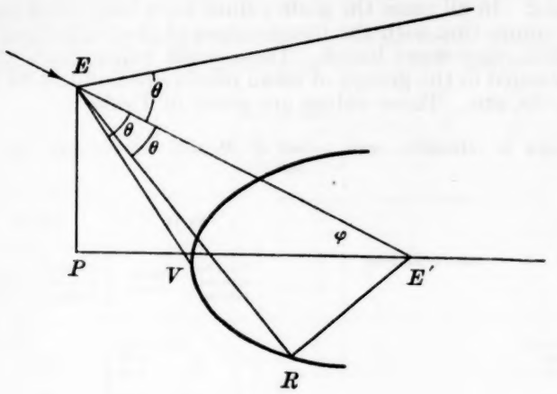

FIG. 4.

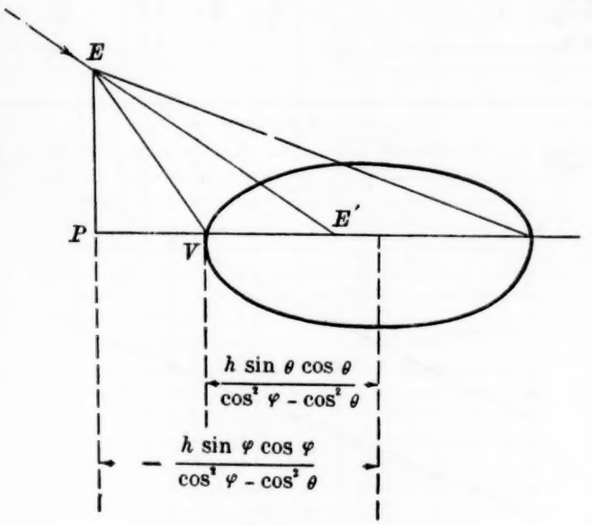

FIG. 5.

8. When the rainbow appears in the sky the air must be still and the space between the observer and the rainbow must be clear from any thick cloud or falling rain, so that the raindrops causing the rainbow fall in a vertical plane and the effective rays from these drops generate the surface of a cone having its vertex at the observer's eye and its axis parallel to the incident rays. Hence it is probable that the sky rainbow is, in general, elliptic in form though it may appear as circular.

To confirm this statement experimentally proceed as follows: When the sun shines from behind you in a laboratory, let your assistant stand at your arm's length and let him spray water drops in a vertical plane perpendicular to your line of sight. You will see a nearly complete elliptic rainbow whose major axis is vertical.

Hence the constancy of the angle between the incident and effective rays gives no more conclusive reason why the rainbow must be a circle.

IMPROVED KITE HYGROMETER AND ITS RECORDS.

By WILLIS RAY GREGG, Meteorologist.

[Division of Aerological Investigations, U. S. Weather Bureau, Apr. 24, 1917.]

Free-air records of relative humidity are obtained by means of the hair hygrometer. In the Marvin kite meteorograph [1] the bundle of hairs is mounted longitudinally in the horizontal screening tube, which also contains the temperature element and recently the anemometer wheel. The meteorograph is attached to the middle back rib of the kite, just behind the front cell, in such a manner that the wind always blows directly through the screening tube, thus insuring good ventilation. In spite of its good exposure, considerable difficulty has always been experienced in obtaining accurate values of humidity, because of sluggishness or "lag" in the hygrometer. Part of this trouble has been eliminated by connecting the element as directly as possible

[1] See photographs published in this REVIEW, October, 1899, Pl. I; in Bulletin, Mount, Weather Observatory, v. 1, pt. 1, Pl. I; also Weather Bureau Bulletin F (Washington 1899), fig. 1 and fig. 5.—C. A., jr.

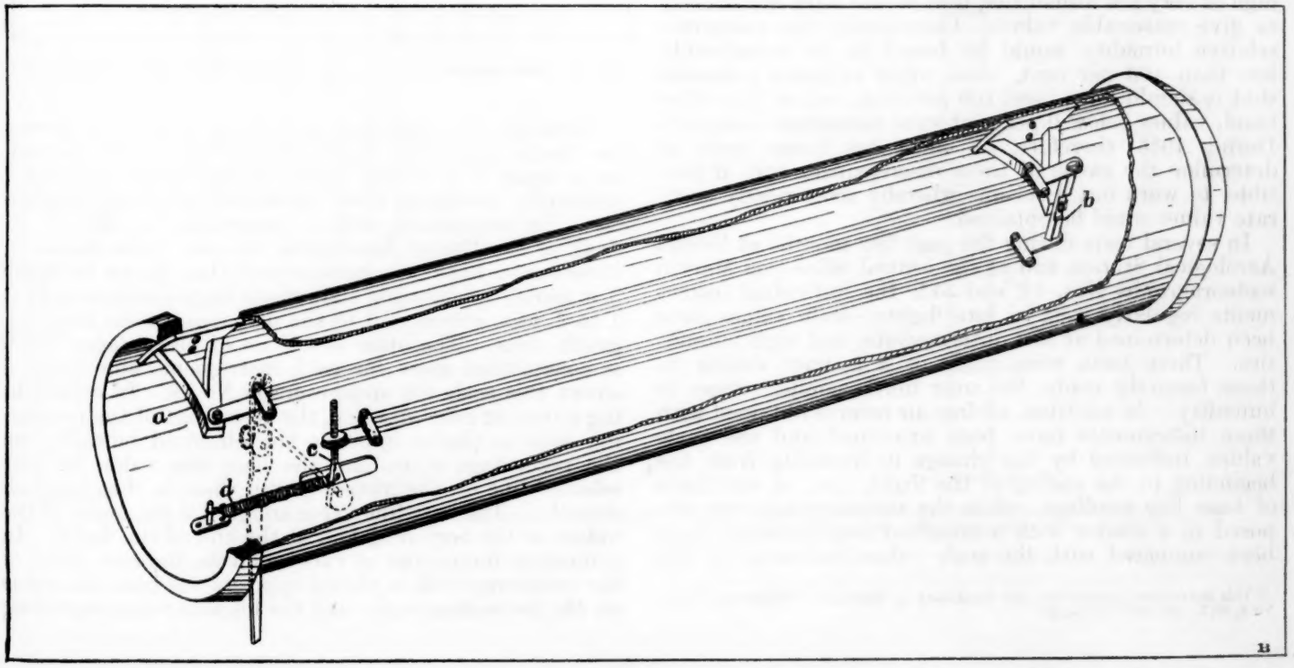

FIG. 1.—Section of horizontal screening tube in kite meteorograph, showing method of mounting hairs of hygrometer. *a*, Fixed post; *b*, Pivoted arm; *c*, Pen arm; *d*, Spring for holding hairs at constant tension.

with the recording pen, thus reducing to a minimum the lost motion in the mechanical bearings. Another radical improvement, introduced by Prof. William R. Blair in 1912, consists in mounting the individual hairs separately instead of in a bundle, as formerly. This new mounting is shown in figure 1. Two sets of hairs are used—one running from the fixed post at *a* to a pivoted arm at *b;* the other, from this point *b* to the pen arm at *c*. A small spring at *d* keeps the hairs at a constant tension. Thus any change in the length of the hairs is at once communicated to the recording pen. Small clamp nuts at *c* enable one to adjust the element so as to keep the pen from moving over too great a space on the meteorograph sheet for a certain change in humidity. Before mounting the hairs they are subjected to the same conditions of temperature and humidity and to the same tension, and are then fastened firmly with shellac. It has been found that the hairs, when thus mounted, respond very quickly to changes in humidity, whereas, when arranged in a bundle they require a relatively long time to change from dry to wet conditions and especially from wet to dry.

Notwithstanding these improvements, scale values determined in tests have frequently failed to agree with those indicated, at the beginnings and endings of free-air records, by the meteorograph traces, for which values of relative humidity were determined by means of a psychrometer. In making these tests the meteorographs were placed in a fairly tight wooden box, in which different humidities were successively produced by means of calcium chloride and blotters soaked with water. An Assmann aspiration psychrometer[2] was used in determining the relative humidity, and was read through a glass window in one of the sides of the box. A fan inside the box kept the instruments well ventilated. By this method a large range in humidity was obtained. Usually we made several such tests for each instrument, and the resulting mean scale values were used in the reduction of free-air records. These scale values worked very well for indicated humidities well within the range of the tests, but, in the case of records for which the pen indicated very high or very low humidities, they would often fail entirely to give reasonable values. Occasionally the computed relative humidity would be found to be considerably less than 100 per cent, when other evidence indicated that it should have been 100 per cent and, on the other hand, values below 0 per cent were sometimes indicated. During 1916, therefore, an effort has beeen made to determine the cause of these discrepancies and, if possible, to work out a scheme whereby more nearly accurate values could be obtained.

In several tests during the past few months at Drexel Aerological Station and at the central office—on Marvin meteorographs Nos. 18 and 575, the individual instruments regularly used in kite flights—scale values have been determined at low, intermediate, and high humidities. These tests were made in a manner similar to those formerly made, but over much smaller ranges in humidity. In addition, all free-air records obtained with these instruments have been examined and the scale values, indicated by the change in humidity from the beginning to the ending of the flight, i. e., at the times of base line readings, while the meteorograph was exposed in a shelter with a standard psychrometer, have been compared with the scale values indicated by the tests. In all cases the scale values have been considered in connection with the mean values of the humidities on which they were based. These scale values were then arranged in the groups of mean relative humidities 20–29, 30–39, etc. These values are given in Table 1.

[2] This instrument is described and illustrated in Milham's "Meteorology," New York, 1912. pp. 70–71.—C. A., Jr.

TABLE 1.—*Humidity scale values of Marvin meteorographs Nos. 18 and 575.*

Mean humidities.	No. 18.		No. 575.	
	Number of observations.	Scale values.	Number of observations.	Scale values.
Per cent.		*Per cent.*		*Per cent.*
20–29	7	1.03		
30–39	12	1.14	11	0.71
40–49	20	1.29	21	.77
50–59	27	1.34	38	.85
60–69	28	1.49	38	.93
70–79	20	1.52	32	1.01
80–89	7	1.64		

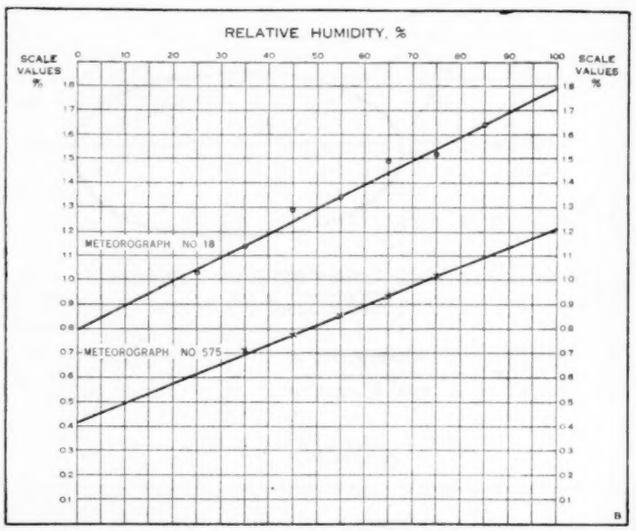

FIG. 2.—Curves showing humidity scale values for Marvin meteorographs Nos. 18 and 575.

Although the individual variations from these means are fairly large, the means themselves, when platted, as in figure 2, give very nearly straight lines, indicating uniformly increasing scale values for increasing humidities. In accordance with a suggestion by Mr. V. E. Jakl, of the Drexel Aerological Station, scales based on these curves have been constructed: One, shown by figure 3, is merely a measuring scale whose large divisions, 0 to 1, 1 to 2, etc., correspond to the divisions on the meteorograph sheet. The other is a scale of percentages which is constructed anew for each instrument, and figure 4 shows this scale for meteorograph No 18. In establishing a base or reference line, the zero point of the measuring scale is placed opposite the observed humidity on the percentage scale, and the base line value for any selected line on the meteorograph sheet is then read off directly. The base-line value adopted is the mean of the values at the beginning and at the end of the flight. In computing humidities at various levels, the zero point of the measuring scale is placed opposite the base line value on the percentage scale, and the humidity corresponding

to any ordinate on the record is obtained from the percentage scale.

There are so many possibilities for errors in humidity observation and reduction that it is not thought that these scales will give absolutely correct values in all cases, but, in the reduction of records thus far obtained, they have indicated more consistent results than any method heretofore used.

FIG. 3.—Measuring scale: Large divisions correspond to divisions on meteorograph record sheet.

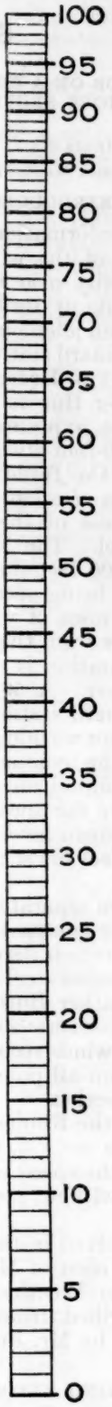

FIG. 4.—Percentage scale, used with scale in figure 4, for determining values of relative humidity for any ordinate on meteorograph sheet from No. 18.

SECTION II.—GENERAL METEOROLOGY.

ANEMOMETER RECORDS ON A BUFFALO OFFICE BUILDING COMPARED WITH THOSE SECURED NEAR THE SURFACE OF LAKE ERIE.

By BENJAMIN C. KADEL.

[Instrument Division, Weather Bureau, Mar. 6, 1917.]

INTRODUCTION.

In order to obtain information concerning the relation between the velocity of the wind on a high city office building and the velocity near the surface of Lake Erie, comparisons were made at Buffalo, N. Y., between the regular Weather Bureau anemometer and an anemometer exposed at the Coast Guard station from January 1 to May 17, and from October 1 to December 31, 1916.

The regular Weather Bureau anemometer at Buffalo has one of the freest exposures in the United States, being mounted on a 40-foot steel tower on the roof of the New York Telephone Co. Building, a modern high office building, the Robinson anemometer being 280 feet above the ground at the base of the building, and 308 feet above mean lake level. The New York Telephone Co. Building is about 2,000 feet due east of the lake front, the intervening space being occupied with city buildings of the business type, none of which rise high enough to shield the anemometer from the wind.

The Coast Guard station is on the outer pier at the mouth of Buffalo River. A 50-foot steel tower, maintained at the Coast Guard station by the Weather Bureau for the display of storm warning signals, was utilized for the installation of the comparative anemometer, the instrument being mounted on a cross arm attached to the flagstaff just above the apex of the tower at a height of 65 feet above the mean level of Lake Erie. The anemometer is thus 243 feet lower than the Weather Bureau anemometer.

The winds have been separately tabulated for the eight principal points of the compass during the period under consideration, the direction determined from the recording wind vane on the same steel tower with the anemometer at the regular Weather Bureau station being used for both stations. The construction of the automatic wind vane is such that the winds recorded under a given direction include those from all points of the compass within 22½° of the given direction.

The indications of the Robinson anemometer as interpreted by the formula $v = V/3$, in which V = the velocity of the wind, and v = the speed of the centers of the cups, have been accepted without correction for the purposes of this paper.

The field work involved in the experiment was carried out under the supervision of Mr. David Cuthbertson, in charge of the Buffalo Weather Bureau office, and the records were transcribed from the automatic register sheets and computed by Mr. Frank A. Math of the same office.

WIND EXPOSURE.

North winds reach both anemometers over a course but little obstructed by buildings or otherwise, such buildings as exist in the region to the north being of a low type as compared with the section to the northeast and east of the Coast Guard station.

There was but little north wind at Buffalo during the period under consideration, the movement from the north representing but 2 per cent of the total, while such north winds as did occur were relatively light and unimportant. The north winds, however, differed from those from other points in that the movements were nearly always greater at the Coast Guard station than at the Weather Bureau station, the ratio of the former to the latter for the entire period being 1.10.

References to the unpublished detailed record show that the Coast Guard anemometer registered less than the Weather Bureau anemometer in 14 instances, that it registered the same in 4 instances, and that it was ahead in 39 instances of the 57 occurrences of north wind during the comparison. Just why the movement of the north winds at the Coast Guard station should exceed those at the Weather Bureau station, does not appear.

Northeast winds must cross the high-buildings section of the city of Buffalo before they arrive at the Coast Guard station. They constituted 13 per cent of the total movement, and were for the most part light, the most important northeast winds of the period occurring on February 12 and 13, when, during a period of 22 hours, 394 miles were recorded at the Weather Bureau anemometer, and 336 miles or 85 per cent as much at the Coast Guard station. The detailed records show but one important instance when there were more northeast winds at the Coast Guard station than at the Weather Bureau station.

East winds, from which the Coast Guard anemometer is most effectively sheltered by the city, were of infrequent occurrence and were generally light and of short duration, constituting 8 per cent of the total. During the entire period the Coast Guard anemometer registered 69 per cent as much as the Weather Bureau anemometer, while during individual east winds the percentage differed, ranging from 74 per cent during a 20-mile wind that continued 21 hours on January 29, to 47 per cent during a 19-mile wind that continued 20 hours on November 20.

Southeast winds skirt the low-lying region along the lake shore and the Buffalo River before their arrival at the Coast Guard station, and therefore suffer but little obstruction. They constituted but 3 per cent of the total, and were for the most part light and of short duration. The most important southeast wind of the period occurred October 19, the maximum velocity for a five-minute period at the Weather Bureau anemometer reaching 48 miles per hour, while at the Coast Guard station the maximum velocity at the same time was but 36 miles per hour. With the gradual clockwise shift of the wind, however, the relative movement at the Coast Guard station increased and at times the Coast Guard anemometer ran ahead, notably when the wind blew from south-southeast; but it fell behind again as soon as the wind reached southwest. It appears that the wind at the Coast Guard station exceeds that at the Weather Bureau office only when it is blowing in a northerly or southerly direction, roughly in the course of a valley or channel that is formed by the Buffalo River to the southeast and the Niagara River to the north.

TABLE 1.—*Hourly wind direction and movement from 7 a. m. to 6 p. m., Oct. 19, 1916; to illustrate change in ratio with clockwise shift of wind.*

	A. M.					P. M.					
Hour	8	9	10	11	XII	1	2	3	4	5	6
Direction	SE.	SE.	SE.	SE.	SSE.	SSE.	S.	S.	S.	SW.	SW.
Hourly movement:											
Weather Bureau	37	39	19	28	33	28	25	27	22	25	24
Coast Guard	26	25	17	24	28	36	33	24	18	19	16
Ratio	0.70	0.64	0.89	0.86	0.85	1.29	1.32	0.89	0.82	0.76	0.67

from the full expanse of the lake, and may therefore be presumed to reach both anemometers free from any but local influences. It is rather surprising, therefore, to find that the average ratio of the Coast Guard anemometer to the Weather Bureau anemometer is nearly as low for southwest and west winds as it is for east winds from which the Coast Guard anemometer is shielded by the city.

RESULTS OF OBSERVATIONS.

Table 2 shows, for each month, the total movement from the various directions for both anemometers,

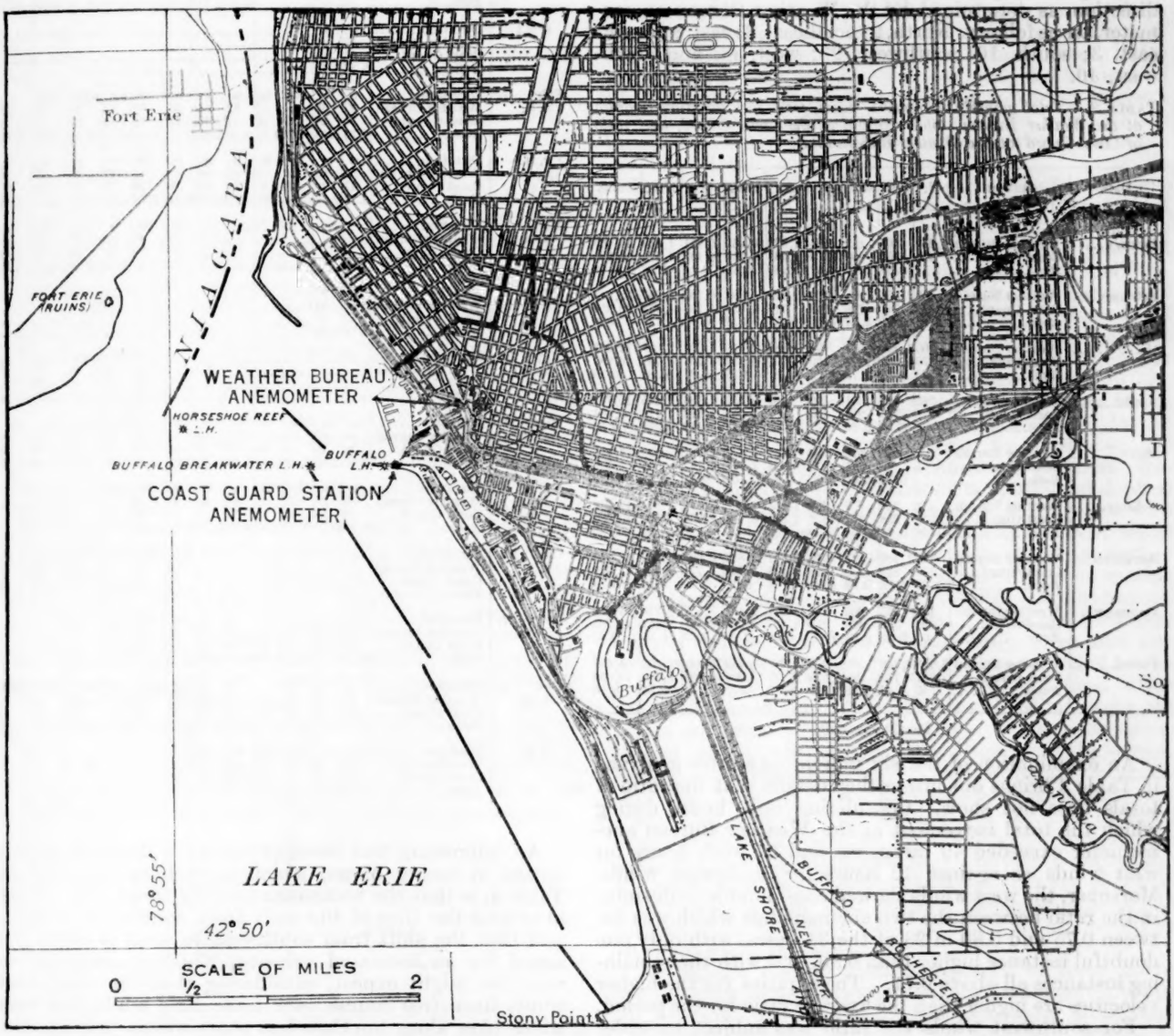

FIG. 1.—Map of Buffalo, N. Y., and vicinity, showing positions of Weather Bureau and Coast Guard exposures relative to city and to lake. Heavy black line incloses area occupied by business houses of the high-building type. (From U. S. Geol. Survey, topographic sheet "Buffalo, N. Y.")

Southwest and west winds are of greatest import to the marine interests, both because they are the offshore winds and because the winds from southwest and west, which together constituted 64 per cent of the total during the experiment, are the prevailing winds of the region and include the high velocities. Winds from points between south-southwest and due west reach Buffalo together with the ratio of the Coast Guard anemometer to the Weather Bureau anemometer. An examination of the table shows that the total wind movement at the Coast Guard station exceeds that at the Weather Bureau station only for winds from the north, a relation consistent through the months of record. The lowest ratio occurs with east winds, probably because the Coast

Guard anemometer is in the lee of the city; but the ratio for southwest and west winds is likewise low.

The total travel by the wind during the entire period was 66,924 miles at the Coast Guard station and 86,422 miles at the Weather Bureau station. Thus the difference or increased travel at the latter station amounts to 22,498 miles, which is 33.8 per cent in 243 feet, or 14 per cent per 100 feet as the average vertical difference between these two anemometers. But it is apparent from a consideration of the data presented that any rule for reducing the readings at one anemometer to those at the other must take direction into account.

The percentages of the total run blowing from each direction, as determined by the Weather Bureau anemometer, are as follows: North, 2; northeast, 3; east, 8; southeast, 3; south, 10; southwest, 26; west, 38; and northwest, 10.

TABLE 2.—*Total monthly movement, miles, from each direction recorded at the Weather Bureau, total recorded at the Coast Guard, and ratio of Coast Guard total to Weather Bureau total.*

Date.	Station.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Total.
1916.										
January	Weather Bureau	233	168	842	121	1,672	6,259	5,754	1,554	16,603
	Coast Guard	273	150	592	109	1,343	4,159	4,107	1,171	11,904
	Ratio	*1.17*	*0.89*	*0.70*	*0.91*	*0.80*	*0.66*	*0.71*	*0.76*	*0.72*
February	Weather Bureau	606	868	998	239	123	1,892	6,169	2,047	12,942
	Coast Guard	695	743	758	213	118	1,354	4,703	1,772	10,356
	Ratio	*1.15*	*0.85*	*0.76*	*0.89*	*0.96*	*0.72*	*0.76*	*0.87*	*0.80*
March	Weather Bureau	260	1,246	1,633	694	485	2,053	4,232	2,038	12,641
	Coast Guard	272	1,001	1,173	559	391	1,539	3,263	1,791	9,989
	Ratio	*1.05*	*0.80*	*0.72*	*0.81*	*0.81*	*0.75*	*0.77*	*0.88*	*0.79*
April	Weather Bureau	245	462	1,341	510	982	2,652	3,186	1,415	10,793
	Coast Guard	258	335	918	360	607	1,547	1,819	1,120	6,964
	Ratio	*1.05*	*0.73*	*0.68*	*0.71*	*0.62*	*0.58*	*0.57*	*0.79*	*0.65*
May[1]	Weather Bureau	8	99	516	180	677	3,179	2,781	533	7,973
	Coast Guard	5	77	341	135	454	1,947	1,785	395	5,139
	Ratio	.....	*0.78*	*0.66*	*0.75*	*0.67*	*0.61*	*0.64*	*0.74*	*0.64*
October	Weather Bureau	481	350	733	651	1,954	4,608	3,616	824	13,217
	Coast Guard	520	258	427	522	1,685	3,703	2,762	762	10,639
	Ratio	*1.08*	*0.74*	*0.58*	*0.80*	*0.86*	*0.80*	*0.76*	*0.92*	*0.80*
November	Weather Bureau	160	1,106	868	359	2,717	3,622	6,055	466	15,353
	Coast Guard	169	843	539	313	2,078	2,799	4,771	421	11,933
	Ratio	*1.06*	*0.76*	*0.62*	*0.87*	*0.76*	*0.77*	*0.79*	*0.90*	*0.78*
December	Weather Bureau	125	427	605	447	1,677	2,487	7,552	1,215	14,535
	Coast Guard	129	352	453	418	1,507	1,936	5,779	1,157	11,731
	Ratio	*1.03*	*0.82*	*0.75*	*0.94*	*0.90*	*0.78*	*0.77*	*0.95*	*0.81*
Period	Weather Bureau	2,118	4,726	7,536	3,201	10,287	26,752	39,345	10,092	104,057
	Coast Guard	2,321	3,759	5,201	2,629	8,183	18,984	28,989	8,589	78,655
	Ratio	*1.10*	*0.80*	*0.69*	*0.82*	*0.80*	*0.71*	*0.71*	*0.85*	*0.76*

[1] For 17½ days only.

An examination of the six individual storms analyzed in Table 3 brings out interesting details that the ratio of totals does not show. Considering only hours during which the total movement at the Weather Bureau anemometer exceeded 49 miles, we find 34 such hours for west winds as against 12 hours for southwest winds. Moreover, the west winds showed considerable uniformity in the ratio between the two anemometers which was between 0.75 and 0.80 in 28 of the 34 cases, with only one doubtful instance higher than 0.80, and with the remaining instances all above 0.71. These ratios for the higher velocities are higher than the average ratio for the period.

For southwest winds the ratio was subject to wider fluctuations, ranging from 0.56 to 0.84 for the 12 hours for which southwest winds exceeding 49 miles per hour were examined.

TABLE 3.—*Hourly wind direction, movement in miles, and ratio of Coast Guard's to Weather Bureau's record during six important storms in 1916.*

Date.		Hour. 1	2	3	4	5	6	7	8	9	10	11	12
1916													
Jan. 13, A. M.	Direction	.....	.....	.....	.....	W.	W.	W.	W.	W.	W.	W.	W.
	Weather Bureau	.....	.....	.....	.....	59	65	67	69	72	67	62	58
	Coast Guard	.....	.....	.....	.....	44	48	52	54	57	52	49	44
	Ratio	.....	.....	.....	.....	*0.75*	*0.74*	*0.78*	*0.78*	*0.79*	*0.78*	*0.79*	*0.76*
P. M.	Direction	W.	W.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Weather Bureau	52	46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Coast Guard	43	35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Ratio	*0.83*	*0.76*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Feb. 7, A. M.	Direction	W.	W.	W.	W.	W.	W.	W.	W.	NW.	WNW	W.	W.
	Weather Bureau	27	36	42	46	52	54	53	52	47	53	56	58
	Coast Guard	20	27	32	35	41	43	41	42	33	42	44	46
	Ratio	*0.74*	*0.75*	*0.76*	*0.76*	*0.79*	*0.80*	*0.77*	*0.80*	*0.70*	*0.79*	*0.79*	*0.79*
P. M.	Direction	W.	W.	W.	W.	W.	W.	W.	W.	W.	W.	W.	W.
	Weather Bureau	61	63	64	59	51	49	51	45	47	43	37	34
	Coast Guard	47	49	48	46	39	38	38	36	37	34	30	30
	Ratio	*0.77*	*0.78*	*0.75*	*0.78*	*0.76*	*0.78*	*0.74*	*0.80*	*0.79*	*0.79*	*0.81*	*0.88*
Mar. 7, A. M.	Direction	.....	.....	.....	.....	.....	.....	SW.	SW.	W.	W.	W.	W.
	Weather Bureau	.....	.....	.....	.....	.....	.....	34	42	56	65	64	63
	Coast Guard	.....	.....	.....	.....	.....	.....	25	30	41	52	48	49
	Ratio	.....	.....	.....	.....	.....	.....	*0.74*	*0.71*	*0.73*	*0.80*	*0.75*	*0.78*
P. M.	Direction	W.	W.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Weather Bureau	59	51	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Coast Guard	42	38	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Ratio	*0.72*	*0.74*	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
May 10, P. M.	Direction	.....	.....	.....	.....	.....	.....	.....	SW.	SW.	SW.	SW.	W.
	Weather Bureau	.....	.....	.....	.....	.....	.....	.....	35	48	54	61	47
	Coast Guard	.....	.....	.....	.....	.....	.....	.....	25	31	30	37	29
	Ratio	.....	.....	.....	.....	.....	.....	.....	*0.71*	*0.64*	*0.56*	*0.61*	*0.62*
May 11, A. M.	Direction	SW.	SW.	SW.	W.	W.	SW.	SW.	SW.	SW.	SW.	SW.	SW.
	Weather Bureau	36	42	41	39	36	32	40	47	47	46	50	50
	Coast Guard	24	26	24	23	22	22	27	30	31	32	35	35
	Ratio	*0.67*	*0.62*	*0.59*	*0.59*	*0.61*	*0.69*	*0.68*	*0.64*	*0.66*	*0.70*	*0.70*	*0.70*
P. M.	Direction	SW.	SW.	SW.	W.	W.	W.	W.	NW.	NW.	.....	.....	.....
	Weather Bureau	52	56	57	57	49	40	30	32	32	.....	.....	.....
	Coast Guard	36	38	40	39	34	28	22	22	21	.....	.....	.....
	Ratio	*0.69*	*0.68*	*0.70*	*0.68*	*0.69*	*0.70*	*0.73*	*0.69*	*0.66*	.....	.....	.....
Oct. 16, P. M.	Direction	.....	.....	.....	.....	.....	.....	SSW.	SW.	SW.	SW.	SW.	W.
	Weather Bureau	.....	.....	.....	.....	.....	.....	20	37	45	46	56	54
	Coast Guard	.....	.....	.....	.....	.....	.....	17	29	38	37	47	42
	Ratio	.....	.....	.....	.....	.....	.....	*0.85*	*0.78*	*0.84*	*0.80*	*0.84*	*0.78*
Oct. 17, A. M.	Direction	W.	W.	W.	W.	W.	W.	W.	W.	NW.	NW.	.....	.....
	Weather Bureau	53	53	52	51	53	49	43	37	38	40	.....	.....
	Coast Guard	41	41	42	41	40	38	31	27	31	42	.....	.....
	Ratio	*0.77*	*0.77*	*0.80*	*0.80*	*0.76*	*0.78*	*0.72*	*0.73*	*0.81*	*1.05*	.....	.....
Dec. 9, A. M.	Direction	S.	S.	S.	S.	S.	S.	SW.	WSW.	SW.	WSW.	WSW.	WSW.
	Weather Bureau	21	20	23	17	22	24	53	56	56	56	62	64
	Coast Guard	23	21	22	19	21	22	43	44	43	45	50	57
	Ratio	*1.10*	*1.05*	*0.96*	*1.12*	*0.95*	*0.92*	*0.81*	*0.79*	*0.77*	*0.80*	*0.81*	*0.89*
P. M.	Direction	SW.	SW.	SW.	W.	W.	W.	.....	.....	.....	.....	.....	.....
	Weather Bureau	66	62	57	57	41	37	.....	.....	.....	.....	.....	.....
	Coast Guard	54	51	48	44	34	33	.....	.....	.....	.....	.....	.....
	Ratio	*0.82*	*0.82*	*0.84*	*0.77*	*0.83*	*0.89*	.....	.....	.....	.....	.....	.....

An interesting fact brought out by a detailed examination of heavy blows, which have been collected in Table 4, is that the maximum velocity frequently occurs at or near the time of the shift from southwest to west, and that the shift from southwest to west is often the signal for an increased velocity, which is contrary to what we might expect, considering that the southwest winds have free course over Lake Erie while the west winds blow along the Canadian shore where, presumably, their free flow is more or less interfered with.

TABLE 4.—*Maximum wind velocity, in miles per hour, for a five-minute period, midnight to midnight, at Weather Bureau anemometer, and time of occurrence as referred to the time of shift from southwest to west.*

Date.	Maximum velocity.	Direction at time of maximum.	Time relative to shift.
1916.	*Mis./hr.*		
Jan. 2	58	w	5½ hours later.
5	60	nw	3 hours later.
10	50	sw	4 hours earlier.
10	50	w	On time.
13	76	w	4 hours later.
Feb. 7	70	w	No evidence.
Mar. 7	80	w	1½ hours later.
Apr. 14	56	w	10 minutes later.
Oct. 25	60	w	50 minutes later.
Nov. 23	52	w	1 hour later.
24	72	w	No evidence.
Dec. 5	68	w	On time.

It would be interesting to know just why the winds that reach the Coast Guard anemometer in full force from the lake are retarded nearly as much as are those from directions which are sheltered by the city. It might be suggested that the retarding effect of the city extends to windward because of the banking of the wind; or that the velocity of southwest and west winds at the level of the Weather Bureau anemometer is increased by the presence of the city or of the building, the air that would ordinarily flow at the lower levels being constrained to flow with the layers normal to the height of the anemometer, thus rendering necessary an increased velocity in order that the greater volume of air may pass in the same time. The evidence furnished by the northerly and southerly winds that suffered no obstruction to their flow, either before or after they had passed the Coast Guard anemometer, indicates that in the case of southwest and west winds the Coast Guard anemometer is slowed down, rather than that the Weather Bureau anemometer is speeded up by the presence of the city. If this is correct, then the Weather Bureau anemometer is more nearly representative of the true velocities over the lake at the height of the Coast Guard anemometer than is the Coast Guard anemometer itself, even though the latter is on the lake shore.

A similar comparison made at Chicago in 1911, showed lake winds stronger at the Life Saving Station than on the Federal Building, and land winds nearly the same at both stations; but in this instance the exposure on the Federal Building was admittedly faulty.[1]

SOME NEW INSTRUMENTS FOR OCEANOGRAPHICAL RESEARCH.

By Dr. HANS PETTERSSON.

[Dated: Göteborgs Högskola, Oceanografiska Institutionen, Feb. 7, 1917. MS. received Mar. 29, 1917.]

When considering the remarkable progress made by meteorological science during the last decades, one should not overlook the fact that this advance has been made possible by a parallel and not less remarkable development in the technique of the science, viz, of its instrumental resources. Both as regards general meteorology and perhaps still more within such specialized branches as the study of radiation or high upper air altitude research (where American scientists take a prominent part) we owe the wonderful equipment of modern research to the inventive genius of men like Cleveland Abbe, R. Assmann, C. G. Abbot, C. F. Marvin, etc. As to recording instruments of all kinds the meteorologist of to-day is perhaps better equipped than any other student of natural phenomena, and certainly much better than the followers of the younger sister science of oceanography.

In a previous note in this REVIEW (see issue for June, 1916, **44:** 338) I have tried to set out the reasons for a close cooperation between meteorologists and oceanographers in an extensive study of the North Atlantic Ocean, of the variable physical conditions of its surface sheet, and of the influences direct and indirect which these latter undoubtedly exert on the weather and the climate of the surrounding continents. In the following pages I intend to give a brief description of some novel instruments which highly facilitate the collection of oceanographical data.

Ever since scientific marine research was for the first time taken up on a broad basis by the International Council for the Study of the North Sea, it has become more and more manifest that if results of any practical value for the fishing industries or for meteorological forecasts are to be derived from this work then the net of investigation must be drawn tighter, the frequency of observations increased, and the field of research expanded. This is specially the case in coastal regions where our investigations have proved physical conditions in the fluid element to be almost as variable as they are in the atmosphere. From our research station Bornö in the Gullmarfiord (west coast of Sweden) we possess unique series of continuous hydrographical observations (salinity and temperature measurements at different depths) which have been made daily for over seven years with few breaks. The results prove that the different water layers, differing in density from each other, instead of being at rest are in a state of almost incessant motion with large displacements both vertical and horizontal taking place in a very short time. Thus the boundary surface between two water layers may, from one day to the next, fall by 10 or even 20 meters, which of course involves a radical change in the hydrographical situation, millions of tons of brackish water being swept out to sea and replaced from below by a simultaneous invasion of saltier water of North Sea origin. At the suggestion of the author a series of synoptic parallel observations of these internal movements, previously only studied at Bornö, were carried out at five different localities during November, 1915, by the Swedish Hydrographical-biological Commission. The results prove that the more considerable internal movements are of a general character and that parallel displacements of the boundary occur almost simultaneously at all the different points of observation.

As regards the practical importance of these movements, they must obviously have a profound influence on fish life. O. Pettersson has repeatedly found particularly large upheavals of the boundary surface to coincide with rich catches of herring during the winter fisheries. The author has compared the above-mentioned hydrographical series with statistics from the local fishery and found that the chances of catching mackerel at Bornö in summer are from four to six times better when the boundary surface of 30 per mille salinity is below its average level than in the opposite case.

[1] *Cox, H. J. & Armington, J. H.* The weather and climate of Chicago, Chicago, Ill., 1914 (Geogr. Soc. Chicago, Bull. 4), pp. 286-289.

Self-recording densimeter.

In order to follow these internal movements more closely O. Pettersson in 1909 constructed a recording densimeter by means of which the hidden displacements of the boundary surface are made to draw their own record. The main features of the arrangement are sketched on figure 1.[1] A large cylindrical copper float is free to move vertically from the surface to the bottom at 30 meters between two guide wires of brass. The float is completely filled with sea water and a little paraffin oil, and is balanced against a counterpoise of solid metal (*B* in the figure) so that it barely floats in water of about 30 per mille salinity at 10°C. Therefore when the corresponding boundary surface rises or falls it will carry the float upward or downward, the movements being transferred to a wheel on the bridge serving as support, and from there to a recording pen and drum on the shore. It is not an uncommon experience to find the float one day floating at the surface in clear salt water and next day out of sight beneath a sheet of brownish water of low salinity, 10 meters or more in depth.

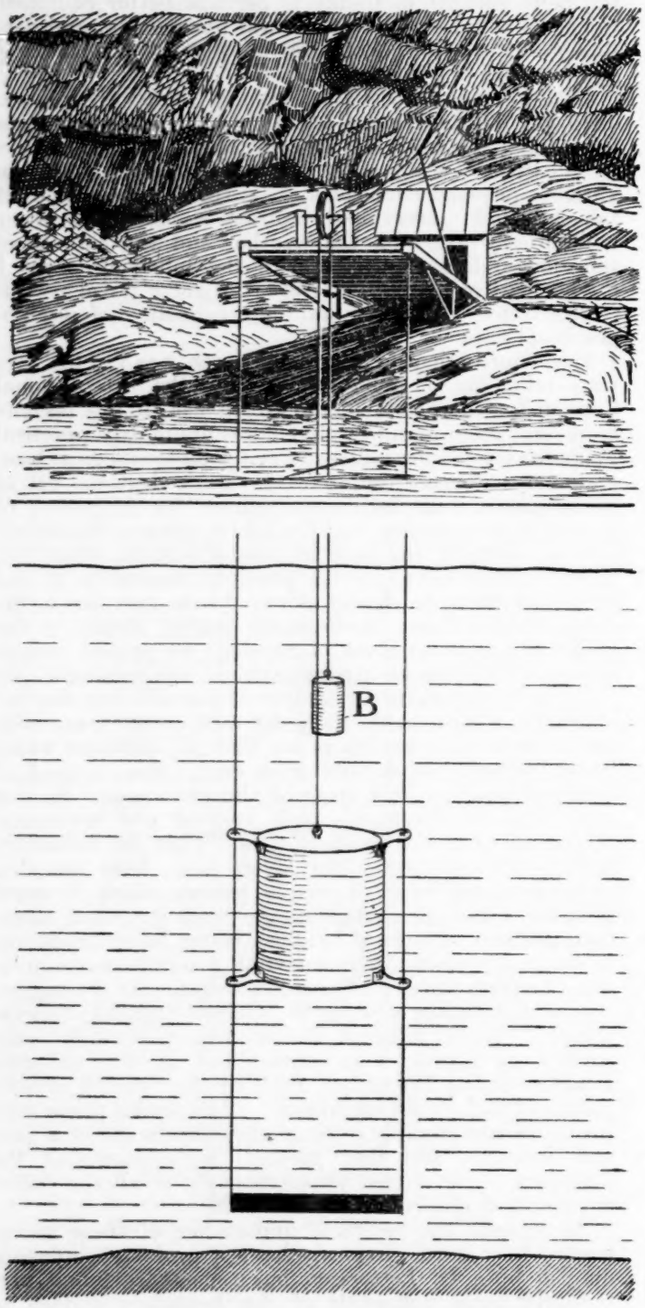

FIG. 1.—O. Pettersson's recording densimeter, out-board portion.

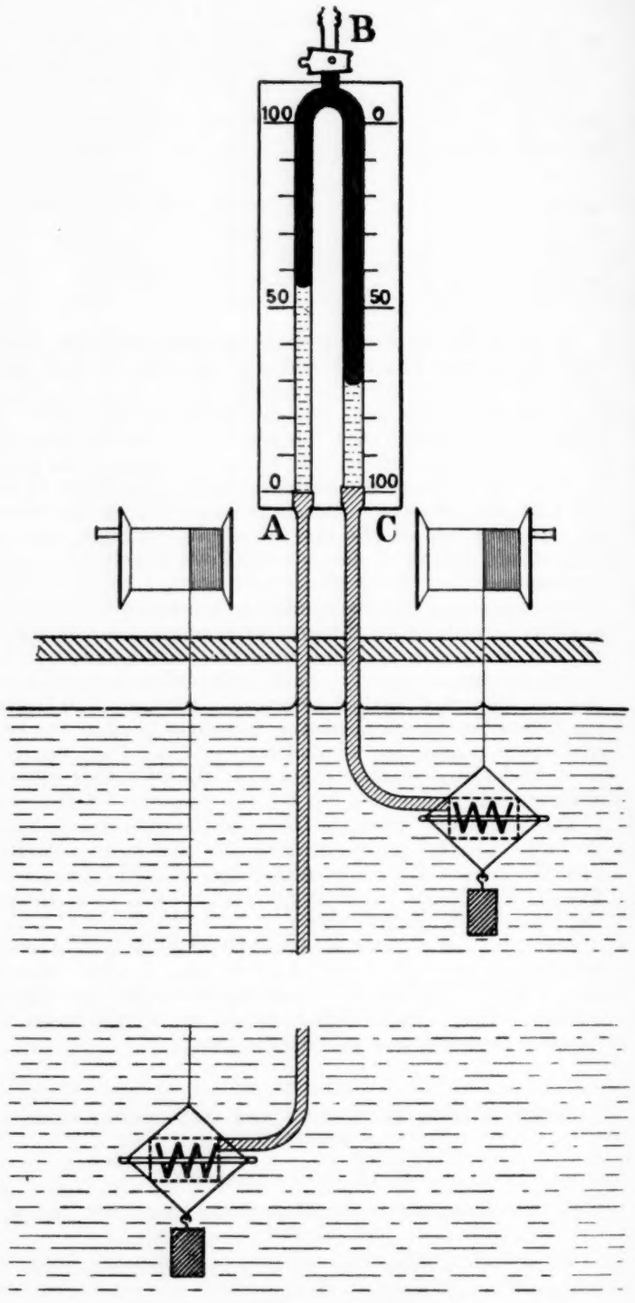

FIG. 2.—H. Pettersson's hydrostatic densimeter.

[1] Figs. 1-6 reproduced by permission of the editor of Annalen der Hydrographie und maritimen Meteorologie.

The record from this instrument, the first by which vertical movements in the sea can be studied, has for years been checked by daily titrations on water samples from different depths and it represents a most valuable material, both for hydrobiological and hydrodynamical research. Thus boundary waves, both of tidal origin and generated by seiches, have been observed and studied theoretically by Nils Zeilon.[3]

A modification of the above instrument intended for work in the open sea, combined with a thermograph, was devised by the author two years ago and ordered abroad, its completion being unfortunately still delayed by the war.

Hydrostatic densimeter.

In order to get a simpler and less expensive arrangement for the study of similar internal movements the author has constructed and tested an entirely novel kind of densimeter based on the hydrostatic principle (see fig. 2). From a vertical, inverted U-tube of glass, ABC, 10 mm. wide and 100 cm. long, two tubes of rubber or metal lead down to depths of say 2 meters and 25 meters, respectively. The whole system is filled air-free with salt water of a known density, d_V, only the upper half of the U-tube containing a liquid of lower density d_L (toluene colored red with azoamidobenzol). If the average density of the water in the fiord between 2 and 25 meters just equals d_V then the toluene will be at rest at equal heights in both branches of the U-tube. But if the salinity in the fiord is increased by an upheavel of the boundary surface, then the toluene becomes pressed over from the "deep" to the "shallow" branch of the U-tube. The meniscus between the toluene and the water in the U-tube, which can be read to within 1 mm. on a vertical scale, will therefore in general rise or fall in a manner exactly parallel to the movements of the boundary surface in the fjord, but on a scale reduced in the proportion $1:r$ where $r=(d_V-d_L)/(d_{25}-d_2)$, d_{25} and d_2 being the density of the sea water at 2 meters and at 25 meters below the surface. Special arrangements at the lower orifices of the rubber tubes serve to retard the intermixture of their contents with the outer water, as well as to prevent any disturbance in equilibrium by the motion of the surface waves and any aspirating effects of horizontal currents.

The instrument is inexpensive, reacts instantly to internal movements, also to such of very small amplitude, and may therefore be used also for the study of Helmholtzian waves. Moreover, the readings are extremely simple, the actual position of the boundary surface being found by a glance at an instrument on the laboratory wall with as little trouble as that of reading the air temperature. It would obviously be of great advantage if the instrument could be made self-recording, but this involves considerable technical difficulties.

In figure 3 the upper curve shows graphically the plotted readings taken from a similar instrument at Bornö during July 27–31, 1916, compared with the simultaneous curve from the recording densimeter. The agreement is seen to be perfect.

Thanks to the kind assistance of Capt. G. Ridderstad, commanding our research vessel, the *Skagerak*, the instrument has also been tested on board during a week in July, 1916, when the ship lay anchored at the entrance to the Gullmarfiord. The results are highly interesting as they reveal the existence of rythmical oscillations in the boundary having a sharply defined period (15 minutes).

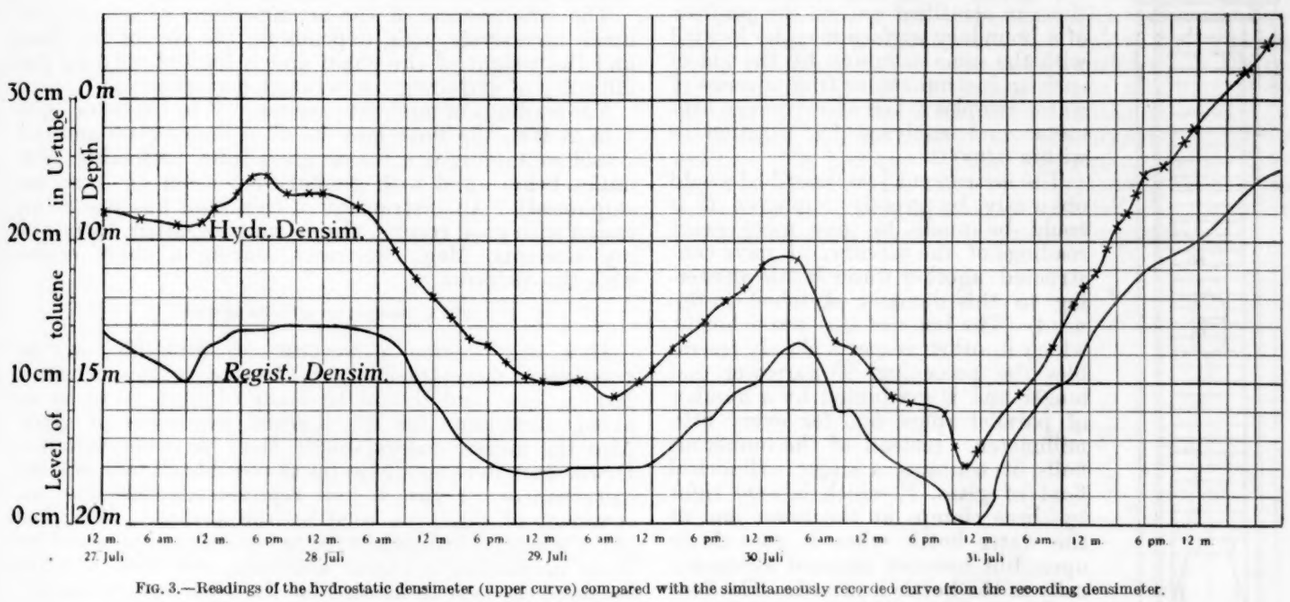
30 cm
20 cm
10 cm
0 cm
Level of toluene in U-tube
Depth
0 m
10 m
15 m
20 m
Hydr. Densim.
Regist. Densim.
12 m. 6 am. 12 m. 6 pm. 12 m. 6 am. 12 m. 6 pm. 12 m. 6 am. 12 m. 6 pm. 12 m. 6 am. 12 m. 6 pm. 12 m. 6 am. 12 m. 6 pm. 12 m.
27. Juli
28. Juli
29. Juli
30 Juli
31. Juli

FIG. 3.—Readings of the hydrostatic densimeter (upper curve) compared with the simultaneously recorded curve from the recording densimeter.

The author hopes that a slightly modified type of the hydrostatic densimeter may be installed on several lightships anchored off the coasts of Denmark and Sweden.

Water bottles for direct measurements of the density.

In order to simplify as far as possible the technique of hydrographical soundings where no high accuracy is necessary, the author has attempted to construct a water bottle which will at a glance give a rough indication of the salinity and the temperature of its contents.

This instrument is intended mainly for the use of fishermen who may derive information of practical value from similar observations. The water bottle, which can be made to inclose hermetically a volume of the water at any desired depth by means of the ordinary closing

[3] Svenska Hydrografisk-Biologiska Kommissionens Skrifter, V.

arrangement with a messenger, has a cylindrical body of some transparent material, glass or "cellon." Within the latter there are, say a dozen of glass balls of different colors, inset pieces of netting at the top and at the bottom of the glass cylinder preventing their escape when the bottle is open. The glass balls have been so balanced as to float in waters of different density, say one at density 1.027, the next at 1.026, and so on. On a simple thermometer mounted axially within the water bottle the temperature can be read to within 0.5 degree (C.), and by counting the number of glass balls afloat or those lying on the bottom of the water bottle when the latter is brought to the surface, one finds the salinity to within say 0.0005. The instrument is extremely simple and has been used with good results by two common fishermen during reconnoitering cruises after herring. Owing to the peculiar hydrographical conditions in stratified waters, the position of a boundary surface may be located with the same accuracy by the aid of such an instrument as from a series of water samples taken at say every fifth meter and analyzed by titration to within 0.00002.

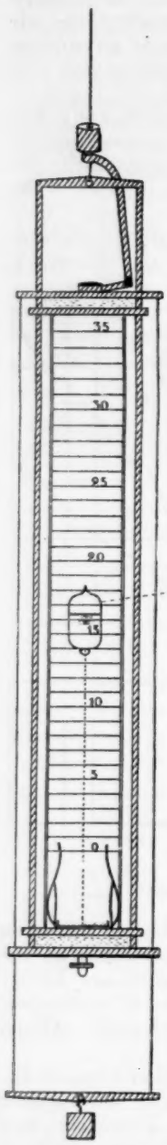

FIG. 4.—H. Pettersson's precision direct-reading density water bottle. F = float with compensating chain.

The instrument just described would obviously be greatly improved if it could be made to give more exact readings of the salinity. I have constructed another water bottle answering to this demand, sketched in figure 4. The body of this water bottle, which in other respects closely resembles the preceding, is narrower and longer and is graduated by a number of parallel rings, one for every fifth millimeter. Instead of the numerous balls, it contains a single cylindrical float of glass, *F*, which is held tight by three clamps at the lower end of the water bottle when it goes down open, but becomes released automatically as the bottle is closed. The float then rises in the cylinder to a height which can be read to within 1 mm. This height is brought into direct proportion to the density of the water, owing to an automatic adjustment of the buoyancy of the float by means of a very fine chain of gold or of gilt metal attached to its lower end. This latter device was suggested to me by my friend Dr. Anders Ångström, of Upsala.

With a float measuring about 40 cu. cm. in volume and a chain weighing (submerged) 24 mg. per cm., a rise of 1 mm. by the float corresponds to an increase in the density of the water of 4 in 100,000 or a change in the salinity of about 0.00006. For ordinary investigations in the upper layers of coastal waters this degree of accuracy is quite sufficient. The temperature is measured on a sensitive thermometer inserted through a hole in the lid. For exact measurements of the temperature of the water in situ the instrument has to be combined with a reversing thermometer. At depths exceeding a couple of hundred meters neither of the two last instruments can be used, owing to the high pressure on the bulbs or on the float.

Areometer with chain.

The automatic adjustment by means of a fine chain attached to the float may also be used for ordinary areometric purposes. In fact, the arrangement represents an almost ideal solution to the old demand for a practical areometer of total immersion. All the errors and corrections caused by surface tension involved in the use of ordinary areometers are avoided with the chain areometer. The only source of error (besides air bubbles and nonhomogeneous temperature in the water) is due to the chain taking up an irregular position, as when it hangs curved instead of depending straight down from the areometer with a sharp bend at right angles where it touches the bottom of the vessel. By gently tapping the glass vessel the chain can easily be brought to a correct position before readings are taken.

The sensitiveness of the arrangement, which may be made excessively high, depends on the size of the float and the weight of the chain and is limited only by the difficulty of excluding temperature disturbances.

For readings of moderate accuracy, 1 in 10,000 or even 1 in 20,000, the float may be of ordinary glass and the vessel containing it a simple glass tube, preferably with outlet below (and with gimbal suspension for work on shipboard). An instrument of this kind has just been tested with good results, also in rough weather, by one of my students, Mag. Sjöstrand, during a short cruise with the *Skagerak*.

[FIG. 5—Received too late to be included.]

If a high degree of accuracy is desirable, say of 1:50,000 or more, the float must have a volume of about 100 cu. cm., and should be made of silica in order to avoid corrections for the thermal expansion of glass. Also the measurements should then be made within a Dewar flask to eliminate as far as possible all temperature disturbances. Figure 5 [not reproduced] shows an instrument of this type used by the author.[3] With the aid of a similar instrument for the deeper samples and for those demanding a higher accuracy, and with a water bottle of the type in figure 4 for the other water samples, the hydrographical soundings of an expedition may be carried out with a minimum of labor and without the necessity of storing any water samples for titration ashore.

An important point with regard to similar instruments is their "range," i. e., the interval of density over which they may be used. With instruments of moderate accuracy or with the water bottle, the position of the float may vary by about 350 scale units which, if the sensibility is taken to be 1:20,000 corresponds to a range of 1:60, say, from $\delta = 1.010$ to $\delta = 1.026$. This range again answers to a maximum interval in salinity of about 20 (not considering the influence of temperature variations) which meets all the requirements of an ordinary hydrographical expedition.

With high-precision instruments the total vertical displacement of the float can not very well be increased beyond 300 mm. If the accuracy is 2 in 100,000 per mm., the range will be about 1:160, or, say, from $\delta = 1.022$ to $\delta = 1.028$, which is again sufficient in most cases (for bottom

[3] The drawing for fig. 5 and the MS for Table 1 were sent by the author at a later date than the balance of the article here published, but the mails failed to reach the editor in time for this issue. See issue for May, 1917.—C. A., jr.

layers in coastal regions as well as for measurements in the open ocean).

Obviously the range of the instrument can in both cases be extended a multiple of times by attaching to or detaching from the float standardized weights of platinum or quartz.

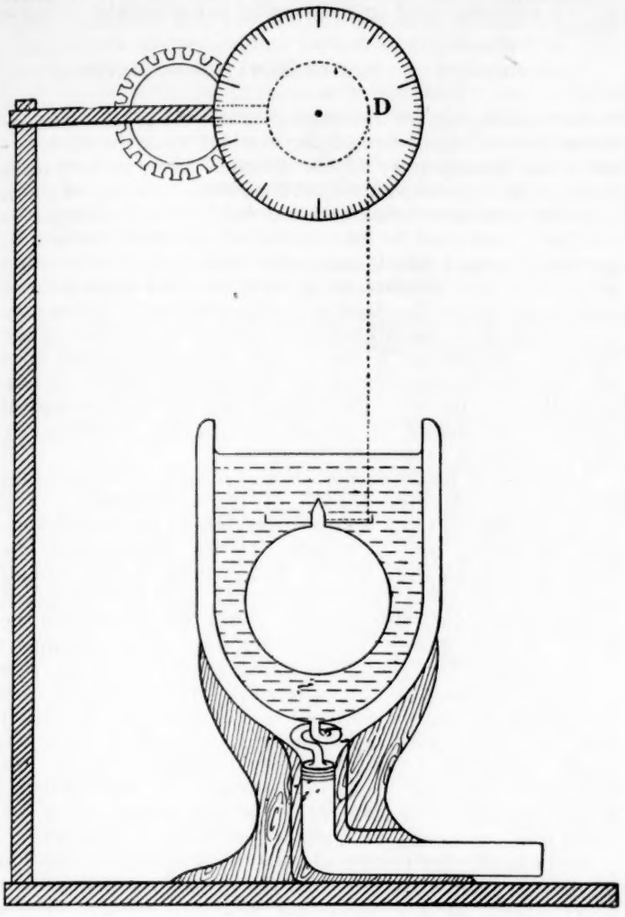

FIG. 6.—H. Pettersson's precision chain-compensated areometer with overhead chain.

A disadvantage of the instrument in figure 5 is the large amount of water required for each measurement, the capacity of the vessel being some 800 cu. cm. Acting on a suggestion by O. Pettersson that the chain may as well be let down on the float from above as depend from it to the bottom of the vessel, the author has had constructed an instrument of the type shown in figure 6. The spherical float is always brought back to its zero position by allowing a suitable length of the chain to be accumulated on a small tray attached to the top of the float, by unwinding the chain from a cylindrical drum with a spiral groove. With a float of 150 cu. cm. (sensibility 1 in 80,000) the net capacity of the Dewar vacuum vessel is only 300 cu. cm., and the range 1:80, the total length of the chain available for measurements being 100 cm.

Recording current meter.

It is technically a most difficult problem to measure currents in the sea at different depths, even with a moderate degree of accuracy. A considerable number of different current meters have been constructed for that purpose. However, also in this case, it has been found desirable for many purposes to keep up the observations for some time, repeating the measurements at regular intervals of time, as for example, when the tidal element of the currents is to be studied. With ordinary instruments such observations are extremely laborious and the strain on the human observers very great. The only successful recording current meter hitherto constructed is that invented by O. Pettersson (modified and improved by the author). Figure 7 conveys an idea of this instrument (vertical section).[4]

A cylindrical envelope of brass, provided with a large rudder which keeps the direction of the current, is kept hermetically closed by a lid and contains the registering apparatus, two opaque glass disks D_1 and D_2, each with a row of numbers round its circumference. At every thirtieth minute those numbers, which happen to be before the aperture of a tiny camera are photographed by a flash from an electric lamp L_1 on a film slowly moved by clockwork. One of the disks carries two compass needles whereas the other disk is turned round by the current outside, acting on a current wheel W below the cylinder. From this wheel the movement is transferred to the interior and to the disk by means of two astatic magnets M_1 and M_2, one inside the other outside, the magnetic force acting straight through the solid brass bottom of the cylinder (no leakage). Each photogram on the film therefore gives two numbers, one representing the average velocity of the current during the last half hour, the other showing its direction at the moment of exposure.

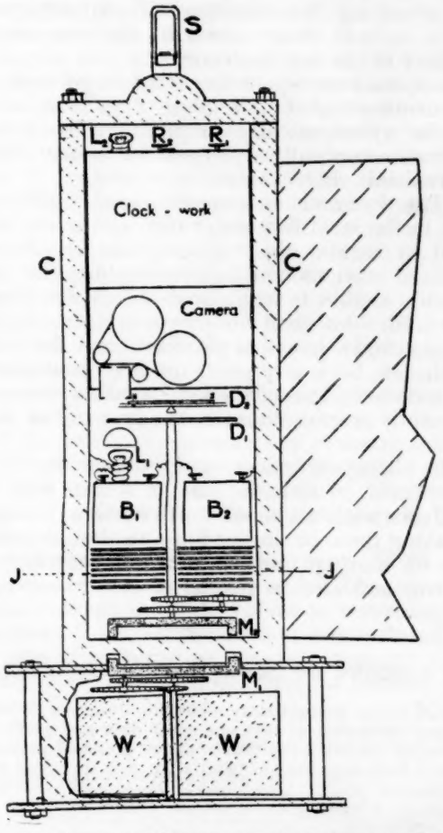

FIG. 7.—The Pettersson recording current meter for deep-sea exploration.

[4] *Pettersson, H.* A recording current meter for deep-sea work. Quart. jour., Royal met'l. soc., London, 1915. Fig. 7 reproduced by permission of the editor of that journal.

The current meter works automatically during a fortnight and may be left for that time unattended suspended from one of G. Ekman's submarine buoys.[4] By this mode of suspension, first suggested by the author, one avoids all the errors usually inherent in the ordinary measurements from an anchored ship and due to the proper motion of the latter. The Ekman buoy, by its double anchorage, is kept at a depth of say, 5 or 10 meters below the surface and there stands as firmly as a rock unaffected by the waves and currents of the surface.

A few of these current meters thus anchored in the Strait of Florida or off the coast of Formosa would serve to keep under observation and to record the amount of water carried northward; thus it would be possible to determine the possibility of using such information in making seasonal forecasts of the temperatures over the eastern United States and Europe, or over Japan.

Conclusion.

Notwithstanding the brilliant results gained through individual efforts like the cruises of Sir Frithiof Nansen or of Johan Hjort and Sir John Murray, the vast field of research offered by the ocean calls for international cooperation on a large scale, if the desired harvest of useful results shall be reaped. The following lines for this work appear to the author as particularly worthy of attention:

I. The existing international network of meteorological observations, suspended during the war, should be extended also over the oceans by means of regular observations from an adequate number of transoceanic liners, reporting by wireless. These telegrams also ought to include observations of the temperature and the salinity of the surface water.[5]

II. A special survey of the most important cold and warm currents and their regions of junction or conflict should be systematically maintained by cruisings of research steamers fully equipped for meteorological and hydrographical observations.

III. The internal movements, both horizontal and vertical in the stratified water near the coasts should be followed by regular observations from a sufficient number of fixed stations and lightships along the coast line. The results should be compared with those from simultaneous hydrobiological observations (prevalence of fish eggs, larvæ, and fish food or plankton) and the yield of the local fisheries, both as regards quantity and quality, and also with observations of the local weather, the occurrence of fogs, and, in cold climates, the freezing of fiords and bights.

If the oceanographers and meteorologists of the United States, of Canada, and of Japan were to unite their efforts with those of northwestern Europe in research along these or similar lines we should undoubtedly soon be on the high road to new and startling scientific discoveries and also to results of the greatest practical value.

ON WORKING UP PRECIPITATION OBSERVATIONS.

A number of the younger station officials, enthusiastic in the development and discussion of meteorological data and particularly that relating to the rainfall of the country, have proposed projects of study that seem to indicate a lack of familiarity with the more fully developed methods of analysis of observational data and processes for eliminating defects or errors due to changes in methods or in observers or other things that bring about discontinuity in a long series of observations. In order to assist such students in the problem of discussing our rainfall observations, we offer the following translation of selected passages in Dr. Hugo Meyer's "Guide to the working up of meteorological observations for the benefit of climatology."[1] Although the original is over 25 years old, the methods presented are still standard and the principles stated are still regarded as fundamental.—*Chief of Bureau.*

HOMOGENEITY OF THE OBSERVATIONAL MATERIAL.

In working up or discussing meteorological observations the very first care of the student must be to determine the homogeneity of the series of observations he is using, i. e., to make sure that the changes in values (both periodic and nonperiodic) arise solely from changes in weather, and that he has excluded all those sudden or gradual changes which may arise from a change in exposure, or in instruments, or in instrumental constants, or from a change in the observer—changes that at times may be of as great a magnitude as a change in location of the station. Therefore, if one is not perfectly certain that the tabulations he desires to discuss in further detail, actually do present the march of the meteorological elements he should undertake to test the homogeneity of the different factors of the series. * * *

Although it really seems to be a matter of course that one should convince oneself of the homogeneity of a series of observations before undertaking further discussion of them; and although Schouw emphasized the point as early as 1827, yet the full bearing of this circumstance has not been fully appreciated until Hann's recent investigations into this point.[2] Hann has also shown the most convenient way for applying tests of homogeneity.

The method for testing the observational material from a station is based on the experience that radical changes in weather are rarely confined to a limited region, rather they take place with the same sign and with more or less equal intensity over extensive districts. Hence *the differences* [in the case of pressure or temperature] *between simultaneous observations at neighboring points, are much more constant than the observed values themselves.*

Accordingly the testing of the observations at a station involves a comparison of the first with the simultaneous observations at a neighboring standard station whose work is of guaranteed accuracy; or if no such standard station is available then the comparison is to be made with simultaneous observations at not less than two neighboring stations.

The first method for comparing the observational results on a meteorological element at different localities which are not too far apart is *the graphic method.* The means for all the years (or months) under consideration are plotted on coordinate paper, using the same scale for each station and arranging the corresponding values at all stations for the same year in the same vertical line; each pair of points for the same locality are then connected by a straight line. In this way one secures a number of broken lines corresponding to the number of stations brought together for comparison. In each of these lines the rises and falls seem to succeed each other without order. On comparing all the curves it must appear, however, that the succession of rises and falls is the same

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[4] *Pettersson, H.* A recording current meter for deep-sea work. Quart. jour. Royal Metl. Soc., London. 1915.

[5] This suggestion by the author has been included in a proposal for the reorganization of the Swedish Meteorological Service, presented to the Government by the Swedish delegates to the International Council for the Exploration of the Sea.

[1] *Meyer, Hugo.* Anleitung zur Bearbeitung meteorologischer Beobachtungen für die Klimatologie. Berlin, Julius Springer, 1891. viii, [4], 187 p., 21½ cm. (Selections are from pp. 43–45, 51, 52, and pp. 132–140.)

[2] See in this connection *Julius Hann.* Untersuchungen über die Regenverhältnisse von Oesterreich-Ungarn. I. Theil: Die jährliche Periode der Niederschläge. Sitzungsber., Kaiserl. Akad. d. Wissensch., math.-naturw. Kl., Wien, 1879, **80-II**, 571–635, particularly p. 573–578.

in all of them, and that the corresponding portions of the different curves are mutually parallel or nearly so. Where there are notable departures from this mutual parallelism, then we have to assume an interruption to the homogeneity of the observations at the station which diverges from the others, and should seek the cause for the divergence. Numerous [European] central meteorological offices employ this method for checking at least the most important meteorological factors in the current monthly reports from all their stations.

This graphic comparison is undoubtedly very reliable, yet it is often advisable to substitute for it *a computational method* and particularly when the series of observations under trial is to be reduced to a longer (i. e., to a normal) period, because then the test for homogeneity can be made to yield at the same time the values needed for the reduction to a normal. * * *

[The omitted portions of the discussion apply particularly to reductions of temperature and pressure observations.]

In the case of precipitation records it is perhaps yet more necessary to reduce the measurements to be compared to the same normal period, for it is well known that the amount of rainfall varies greatly with the time and the locality. At first glance, however, these very reasons appear to make such a reduction very difficult. According to Hann,[3] however, this may be carried out with such certainty that for places having only a short series of observation (i. e., less than 10 years) we may, with the aid of the long series at a neighboring standard station, deduce the normal annual amount and its annual period with greater certainty than it is possible to do from the actual measurements alone. Kämtz early expressed the opinion that the seasonal rainfalls of neighboring stations would show mutual relationships, and Hann has not only confirmed this opinion for the seasonal but also shown a great agreement between the monthly falls of stations not too far apart. To be sure this agreement does not appear between the absolute amounts of the rainfalls; but it is all the more striking between the ratios of the monthly to the annual amounts in the relative amounts of precipitation. The latter are almost the same over considerable areas. Accordingly, if we have only a short series of observations for a station **A**, while for a neighboring station **N** we have the mean precipitation, s, for the normal period, an amount we may call s_n, then Hann derives the normal rainfall at **A** for the same normal period, or s_a, by means of the relation

$$s_a = s_n(A/N),$$

where A and N are the rainfalls at the stations **A** and **N** for corresponding years. To determine the normal march in the annual period for the station **A** we then have to assume that the relative distribution among the months is the same for both stations. Thus s_a is to be multiplied successively by the percentage rainfall of the successive months at the standard station **N**.

This method of reduction is not admissible, however, when stations are rather far apart and particularly not for stations differing more than but little in altitude. Furthermore, "Stations on divides should not be compared with valley stations, even when the horizontal and vertical intervals are slight. In general, however, monthly means derived in this manner possess much greater reliability than means from direct observations which do not cover more than, say, 10 years. Naturally scientific interest requires that these direct means shall also be published."

[When the observational series at one and the same station has been interrupted by changes in exposure, particularly of the raingage, the changes constitute just so many breaks in the homogeneity of the station's record; it should be the first task of the student to secure from the broken record a series of homogeneous observations at the station for the whole time over which observations extend.]

PRECIPITATION OBSERVATIONS.

* * * The rainfall tables present first of all the *mean amount of precipitation of the individual months*, and almost always from direct observations. But these values are not directly comparable; for the months are of different lengths and, other things being equal, the longer month will have the greater rainfall. In order, therefore, to secure the true annual march of rainfall one must reduce the different sums to months of equal lengths, which can be accomplished by making the rainfall proportional to the length of the month. Quetelet[4] and Kreil[5] give in their tables the precipitation per month-day; that is, they divide the mean monthly sums by 28, 29, 30, and 31, respectively. Renou[6] reduced the months to the normal length of $365.25 \div 12 = 30.44$ days. In the writer's investigation of the distribution of precipitation in Germany[7] the month was treated as having a normal length of 30 days, and that decision will here be adhered to because it is somewhat more convenient even though somewhat less exact than Renou's reduction to 30.44 days. In the writer's procedure the February means are to be multiplied by 1.06 and those of the 31-day months by 0.95 as reduction factors.

In this case also one may hold yet closer to the direct observations by assigning the amounts for January 31 and March 1 to the sum for February, in which case the first four months of the year need no further recomputation. The writer's method is perhaps deserving of adoption in preference to those of Quetelet and Kreil—for the further reason that it is more in harmony with the procedures already proposed for other elements [e. g., temperature means]. This method is, however, far from being a generally accepted one, therefore the investigator should never fail to specify whether or no the monthly means have been reduced. Of course the mean annual total will be the sum of the unreduced monthly means.

It is quite sufficiently accurate to give the amounts to whole millimeters, even in the case of the longest series of observations; because the measurements themselves are not sufficiently accurate to justify the retention of the tenths of a millimeter.[8] However, it is advisable to perform the rounding off only on the computed means.

In comparing the annual rain periods of different localities the process is greatly aided by expressing the individual reduced monthly values as percentages of the total amount (i. e., of the sum of the reduced values). In this case it is proper to take into account the tenths of a millimeter, as has been done in column 2 of the illustrative Table 29, below.

[3] *Hann, Julius.* Untersuchungen über die Regenverhältnisse, etc. II. Theil: Veränderlichkeit der Monats- und Jahresmengen, gleichzeitige Vertheilung der letzteren in der Periode 1849–1878. Nachtrage: Fünftägige Mittel des Regenfalles und der Regenwahrscheinlichkeit. Sitzungsber., Kaiserl. Akad. d. Wissensch., math.-naturw. Kl., Wien, 1880, II. Abth., 81: 45–79, particularly p. 57.

[4] *Quetelet, A.* Climat de la Belgique, 5. partie. Ann., Observatoire de Bruxelles, 1852, § 3.

[5] *Kreil.* Klimatologie von Böhmen. Wien, 1865. p. 43.

[6] *Renou, E.* Étude sur le climat de Paris, 2. partie. Annales, Bur. cent. météorol. de France, Paris, 1883. I, p. 259–277.

[7] Hugo Meyer *Fn* Aus dem Archiv der Deutschen Seewarte, 1888, 11, No. 6.

[8] *Riggenbach.* Die bei Regenmessungen wünschbare und erreichbare Genauigkeit. Verhandl., Naturforsch. Gesellsch., Basel, 1888, Pt. VIII, p. 579.

The amount of precipitation belongs to those meteorological elements, which possess a fixed lower limit while there is no upper limit. We accordingly may except that in general the arithmetical mean is larger than the most frequently observed value, and that the positive departures, Δ_+, from this mean are rarer and therefore larger than the negative departures, Δ_-. As we have seen elsewhere [German text, p. 31] this expectation has been confirmed by experience, and even for regions where rainless months do not occur.

For this reason it would be of great interest to ascertain the "scheitelwerth." To do this for the monthly means, however, would require a greater number of years of observations than are available. Even the longest series in our possession permit us to secure but an approximate idea of the grouping of the individual values about the arithmetical mean. Since the assymetry of distribution of the individual values is very considerable in the case of rainfall, the general law soon appears after all. Thus, for example, I have arranged the 50 years' rainfall measurements at Geneva, published by Plantamour,[9] in successive 10 mm. groups for the two extreme months of February and October, with the result shown by Table 28.

TABLE 28.—*Frequencies of the groups of stated amounts of rainfall at Geneva (based on Plantamour's compilation of 50 years' records).*

Group.	February.	October.
mm.		
0 to 9	5	
10 to 19	12	1
20 to 29	10	1
30 to 39	6	5
40 to 49	3	2
50 to 59	5	2
60 to 69	3	4
70 to 79		4
80 to 89	5	7
90 to 99		5
100 to 109		3
110 to 119		
120 to 129		1
130 to 139		5
140 to 149	1	1
150 to 159		2
160 and over		7
Means	37 mm.	101 mm.

They show, as was to be expected, that the individual values crowd about a point situated between the arithmetical mean and the lower limit; and that the influence of the lower limit on the arrangement of the individual values is plainly recognizable even in the rainiest month.

Further on we shall see that the conditions are quite similar for the mean amount of precipitation of a rain-day. A day having a rainfall equal to the mean ranks as one of the very wet rain-days (zählt zu den sehr ergiebigen Regentagen), the overwhelming majority of all days with precipitation bring, in our climate, considerably less amounts than might have been inferred from the mean value [mean daily rainfall].

As regards the monthly amounts of rainfall it follows from what has been said, that since it is not practicable to determine accurately the corresponding "scheitelwerth" it is at least desirable to tabulate the numbers of positives, Δ_+, and negative departures, Δ_-, from the means. In fact this would seem to be quite necessary in the case of regions having rainless months if one would avoid a wholly distorted view of the rainfall relations. Supan [10] has proposed to compute the "*probability of total lack of rainfall*," a suggestion which certainly deserves a consideration it has not yet been granted.

The difference between the mean rainfall of the month with heaviest average fall and that of the month with the smallest average fall gives the *amplitude of the annual periodicity* (for Borkum: October − May = 52 mm.) while the ratio between the two gives the *relative annual range* (for Borkum = 2.3).

As in the case of the other meteorological elements, the *mean departure of the monthly rainfalls* has long been determined by adding the departures from the arithmetical mean, disregarding their sign, and dividing the resulting sum by the number of departures. But since, as we have seen, the number and therefore the sum of the Δ_+ differ considerably from the Δ_- it is preferred to compute the mean positive and the mean negative anomalies separately. In this way we ascertain the upper and the lower limits between which the amount of precipitation fluctuates on the average. The mean rainfall will lie nearer the lower than the upper limit.

The reduction of the monthly rainfall observations to months of normal length will as a rule be performed on the means, and it is only in exceptional cases that previously reduced series will be available for immediate discussion. On this account it is advisable to compute Δ_+ and Δ_- for the unreduced values. A procedure all the more permissible since we do not treat these as final in any case. The reason for this is that in general the amount of the mean departure of a number of individual observations from their mean bears a certain relation to that mean [as the author points out in discussing wind observations]. We secure values which better represent natural conditions if we divide the mean departures by the magnitudes to which they relate, i. e., instead of the mean departures we discuss the quotients from their division by the mean values of the monthly rainfalls which quotients we call *the mean relative departures*. This method seems to be all the more appropriate for precipitation data when the departures are very large in comparison with the value by which they are formed. If now, as we have assumed above, we use the unreduced monthly values in computing the departures then we must be careful to use the unreduced mean monthly rainfalls as the divisors in deriving the relative departures; thus we secure again a result that is independent of the differing lengths of the months. This is the way in which we derived the values entered in columns 5 and 6 of Table 29.

Precipitation tables should be further enriched by incorporating the values of *the absolute extremes*. These bear the same relation to the means as do the mean departures; the extremes on the side of the excess falls are throughout more pronounced (bedeutender) than those on the side of the deficient falls. To be sure, here also the different lengths of the months are of influence; however, it seems this is not important, at least for north German conditions (see the work referred to in footnote 5 above), so we need not take it into consideration. It seems advisable to make no reduction at all rather than to undertake a doubtful one, and all the more since the absolute extremes are of interest, first of all, as direct observations.

The sum of the greatest and the least departure gives the "*absolute*" *range* in rainfall of the year's subdivisions during the given series of years. Here also I do not consider the relation to the mean.

[9] *Plantamour.* Nouvelles études sur le climat de Genève. Mem., Soc. de phys. et d'hist. nat., Genève, 1876, **24**: 648.

[10] *Supan,* ——. Petermanns Mittheilungen, 1886, **32**, No. 132. Literaturverzeichniss, p. 36.

TABLE 29.—*The manner of presenting the character of the precipitation of a locality; illustrated by the character of the precipitation at Borkum (6° 45′ E., 53° 35′ N.) during 1876–1885.*

Month.	Reduced depth.		Departures.				Extremes.		Extreme range.	Probability of a day with—		Rain-density.	Maximum in 24 hours.
			Number of.		Mean relative.		Maximum.	Minimum.		>0.0 mm.	>1.0 mm.		
	1	2	3	4	5	6	7	8	9	10	11	12	13
	mm.	*Per cent.*	Δ +	Δ −	+	−	*mm.*	*mm.*	*mm.*			*mm.*	*mm.*
January	44	5.8	5	5	0.40	0.40	94	16	78	52	32	2.8	22.1
February	56	7.4	4	6	0.46	0.31	96	25	71	63	42	2.9	21.9
March	49	6.5	5	5	0.42	0.42	112	10	102	52	37	3.2	20.5
April	42	5.5	5	5	0.36	0.36	74	9	65	43	24	3.2	25.4
May	39	5.2	4	6	0.67	0.40	97	6	91	45	28	3.8	16.0
June	51	6.9	4	6	0.63	0.42	128	11	117	47	31	3.7	30.0
July	68	9.0	5	5	0.42	0.42	130	3	127	57	39	3.9	32.2
August	87	11.9	4	6	0.59	0.39	156	30	126	57	40	5.1	31.2
September	79	10.4	4	6	0.39	0.26	172	41	131	57	42	4.6	31.5
October	91	12.1	4	6	0.39	0.26	170	42	128	67	49	4.5	25.6
November	83	11.0	4	6	0.38	0.25	157	38	119	68	51	4.1	22.9
December	63	8.4	4	6	0.40	0.27	95	22	74	64	46	3.3	15.2
Year	764	100	5	5	0.12	0.12	942	589	352	56	38	3.7	32.2

The rainfall of any locality is, however, by no means adequately presented by the mere monthly mean falls.

One must also determine the precipitation falling within shorter intervals of time, and compute the frequency with which precipitation occurs.

And here the first question is: How define a "*day with precipitation*"?

[Various definitions have been adopted and proposed; the author decides to adopt as a rain-day "a day on which more than 0.0 mm. of precipitation was measured" and urges Hann's proposal universally to supplement this with a statement of the number of the days on which "at least 1 mm. (0.04 inch) precipitation was measured" (columns 10 and 11 in Table 29)].

On account of the various lengths of the month, *the probability of rain*, i. e., the number of rain-days in the month divided by the total number of days is the preferred form of publication. The good agreement between the values in columns 10 and 11 of Table 29, based on different definitions of a rain-day at Borkum, is by no means a general occurrence.

It is more or less common practice to compute and publish the *mean density of precipitation* or *mean rain intensity*, obtained by dividing the mean amount of precipitation by the mean number of rain-days (>0.0 mm.); but the significance of this factor is often overestimated. It is here expressly pointed out that the rain-intensity is only approximately the amount which is most likely to occur on a rain-day; the latter amount is quite considerably smaller. It is a rule, for all values relating to rainfalls, that the "scheitelwerth" is smaller than the arithmetical mean.

The greatest amount of precipitation during a day is of distinctly greater interest than the rain-density. The maximum fall in one day, accompanied by the year of occurrence, should never be omitted from a table of precipitation. If it is practicable to give more precise information as to the duration of considerable falls, this would be very welcome; because in many respects, e. g., in the problems of Hydrotechnics, it is of prime importance to know the volume of water which falls in intense downpours of shorter duration than 24 hours.

The values here discussed have been collected in Table 29 for the island of Borkum (lat. 53° 35′ N., long. 6° 45′ E.) off the mouth of the Ems. They must be regarded as the necessary elements for describing the periodic changes in the precipitation of a locality. However, it is urgently recommended that, whenever it is in any way possible to do so, the rainfall be treated in yet more detail and that first of all one determine *the frequency with which certain threshold values* (Schwellenwerthe) *are crossed* in the precipitation of a day. Among other advantages, such a computation also brings one to a correct estimation of the rain-intensity. For a long time very little work has been done along this line, but the little we have already is rich in interest. Only in this way may one secure a sharp picture of the rainfall conditions and relationships.

TORNADO OF APRIL 5, 1917, AT TAMPA, FLA.

By WALTER J. BENNETT, Meteorologist.

[Dated: Weather Bureau Office, Tampa, Fla. MS. received Apr. 14, 1917.]

At 7 a. m. (90th meridian time) on April 5, 1917, a low-pressure area of considerable intensity was central over Illinois, with its longer axis extending north-northwest to south-southeast. Strong winds had occurred on the coast of northwestern Florida during the night. At Tampa the weather was cloudy and warm, the temperature being about 7 degrees above normal at the 7 a. m. observation. The barometer was falling slowly, and the southwesterly winds were increasing. At 9:50 a. m. small-craft warnings for the Tampa district were issued as follows:

Hoist small-craft warnings. Fresh to strong west and northwest winds, probably thunder squalls.

An order for small-craft warnings was later received from the central office.

The maximum wind at the station was 26 miles per hour from the southwest at 11:05 a. m. and the wind continued above 20 miles per hour until about 1:50 p. m. The first thunder was heard at 12:45 p. m.; rain fell from 1:12 to 1:44 p. m. yielding the amount of 0.46 inch for that interval. The barometer continued to fall slowly until after 1 p. m. and then it suddenly rose about 0.02 inch.

A violent thunder squall, coming from the southwest, struck Seddon Island (*A* of fig. 1) about 1:40 p. m. and passed across Hookers Point (*B* in figure). At Seddon Island the wind velocity was estimated at about 90 miles an hour. An outbuilding and a smokestack were wrecked

and the blow lasted less than a minute. At Hookers Point small houses were overturned and the pump house of the Mexican Petroleum Co. was wrecked. No funnel-shaped cloud has been reported seen over the bay, Seddon Island, or Hookers Point, but this squall seems to mark the incipient stage of the tornado.

After crossing Hookers Point, *B*, the storm apparently lifted, as no reports were received of damage on the bay shore southeast of Tampa, nor could I find any trace of its path along the road near *C*. Its full force was felt at *D*, and its track could be traced back only a few hundred yards west-southwest of *D*. At *D* the Flatwoods Baptist Church was wrecked. The east end of the building collapsed, possibly from explosive force of imprisoned air, but the wreckage had more the appearance of being pushed forward in the direction in which the storm was advancing.

At *E* the house of J. A. Rayborn was turned over on its side, apparently it also was pushed forward with the storm's advance and showed no evidence of explosion. Harley Rayborn, the 5-year-old son of Mr. Rayborn, was instantly killed; Mr. Rayborn who was also in the house at the time, had a rib broken and his back sprained; while Mrs. Rayborn was bruised and an infant son had his arm broken.

The Rayborn buildings were about two miles southeast of the village of Mango. The storm passed south of Mango a little after 2 p. m. From *D* to *F* the track of the storm could be readily followed. Apparently it lifted and settled several times. In some places trees were uprooted or broken off, in others only the upper branches were broken off and in still other places no damage at all could be seen for a short distance.

The storm crossed the railroad and the brick road at a very small angle, between the villages of Mango and Seffner. Somewhere along here an automobile was overturned and its top carried off.

At *F*, the house of M. B. Gray was lifted off its piers and carried forward about 7 feet, but was not badly wrecked. An immense tree just north of Mr. Gray's house was torn up by the roots. The spread of the roots torn up exceeded 20 feet.

The Methodist church at *G* was completely demolished, apparently pushed forward with the advance of the storm. The porch of the parsonage just north of the church was torn off. Damage was also done to the houses of Dr. J. L. Douglas, W. B. Pemberton, J. H. Spencer, Mr. Reynolds and the Hill House, all at Seffner. The storm passed over Seffner about 2:20 p. m.

At *H* many magnificent oaks of the Seffner picnic grounds were uprooted and broken. Beyond *H* the damage was less marked but the track could be followed as far as *I*. Later reports indicate that the house of R. L. Moore, on the Dr. A. M. Barns old place, 2 miles north of Plant City, was moved from its pillars and considerably damaged. Buildings on the old Covington place (McNeill estate) were moved or damaged, and other minor damage resulted in the same vicinity. At this point the storm was moving northeastward. It evidently came down again with destructive force at a point somewhere near *J* on the map, thus making the extreme length of the path about 24 miles.

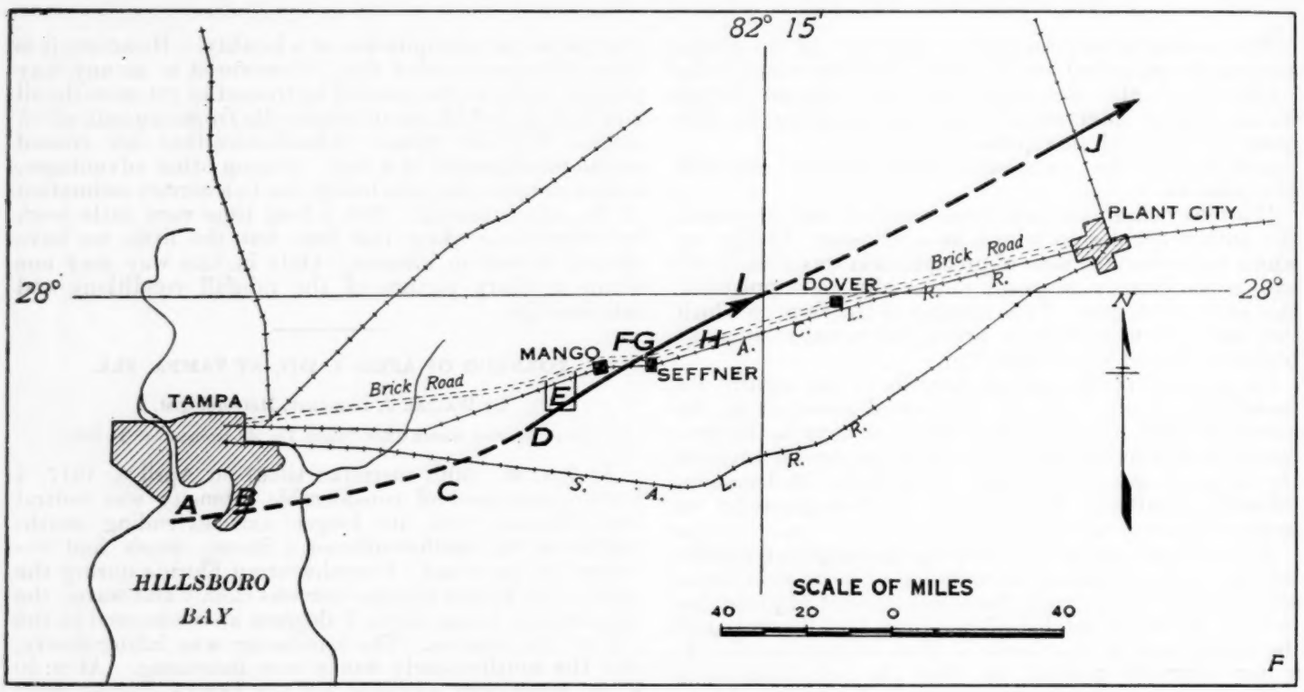

Fig. 1.—Path of the Tampa, Fla., tornado of April 5, 1917.

The appearance of the cloud as reported at Mango and Seffner was funnel shaped, black or very dark gray, with no glow. No meeting of clouds was reported. No lightning was seen to issue from the funnel cloud, although it was preceded by a thunderstorm.

The precipitation was not very great, probably not much more than half an inch at any place, and lasting a short time. The precipitation ended abruptly with the passing of the storm, and the sky cleared rapidly. There was no hail. The general direction of motion of the tornado was from west-southwest to east-northeast.

The whirl in the funnel cloud was plainly seen by a number of observers, and was counter-clockwise. It was not plainly evident in the distribution of the débris. A number of trees were twisted, some twisted off, and the twisting was mostly in a counter-clockwise direction. By far the larger number of trees felled, however, fell forward as though blown down by a straight wind. Some made different angles with the path of the storm, but no regularity could be detected, either in the center line of the path or on either side. The path was nowhere clear cut, many trees being left standing here and there even where the storm apparently had most force.

The length of path from *A* to *I* was about 14 miles; the path over which the funnel cloud was actually observed, *D* to *I*, was about 7 miles. The apparent speed of advance of the storm—reckoned from time observations at Seddon Island, Mango, and Seffner—was about 20 miles per hour and this agrees closely with the estimate of several observers. The width of the path was about a hundred yards at the point of greatest destruction.

The only person killed was the Rayborn child.

Tornadoes are uncommon in central Florida and the occurence of this one is for that reason more noteworthy. None has been recorded in this vicinity since the opening of the Tampa office of the Weather Bureau in 1890; but according to newspaper accounts one of considerable intensity crossed the northern part of the city on March 17, 1887.

TORNADO OF MARCH 23, 1917, AT NEW ALBANY, IND.

By FERDINAND J. WALZ, Professor of Meteorology.

[Weather Bureau Office, Louisville, Ky., Apr. 7, 1917.]

New Albany, Ind., is situated on the north shore of the Ohio River, opposite the west end of Louisville, Ky. Its population is about 26,000. A short distance back of the city proper there is a range of high hills popularly known as "The Knobs," but which in reality might be called bluffs of the Ohio River. The city is built on the flood plain at the base of these "Knobs," which were previously supposed to offer complete protection from tornadic and similar destructive storms. The tornado of March 23, 1917, however, came from beyond these "Knobs," passing over a portion known as "Silver Hills," whence it descended into the valley or basin lying between these hills and the Ohio River. It showed strength and great destruction occurred from the base of Silver Hills eastward.

The storm moved along a nearly straight path in an east-northeast direction, cutting a wide swath through the entire north side of the city. The width of the path of practically total destruction varied between 1,000 and 1,500 feet, with an area along each side varying between 600 and 1,000 feet in which there was a great deal of damage, mostly in spots. The length of the path of the storm, as shown by the destruction in New Albany and vicinity, was about 3½ miles. The storm continued on, however, in the same east-northeast direction and crossed the Ohio River into Kentucky about 10 miles above New Albany. It caused considerable damage at Harrods Creek, Ky., which lies in a direct east-northeast line from New Albany (see fig. 1 on p. 170).

Many articles of furniture and clothing, and other débris carried away by the storm, were found on farms and fields in Kentucky 25 to 40 miles from New Albany, whence they came. A family picture, which was in a house occupied in part by the James Franconia Grocery, Vincennes Street and Charlestown Road, New Albany, was found at Skylight, Ky., having been carried a distance of 25 miles. Also a jar of sweet pickles from the same grocery was found in a ditch on the same farm, the jar being uninjured. In the same vicinity were found articles of clothing, shingles, roofing material, flooring, weatherboarding, a kitchen safe door, letters, and papers.

In New Albany 45 persons, men, women, and children, were killed outright, or have died since from their injuries; several hundred others were injured, a number of whom will probably succumb to their injuries. Between two and three hundred houses were destroyed, including several manufacturing plants, one large greenhouse, two schoolhouses, and one fire-engine house and tower, while several hundred more houses were damaged. Practically 2,500 people, including between 350 and 400 families, were made homeless.

The district which suffered most severely consisted of cottages occupied and mostly owned by working people, and with their cottages went not only their homes but their household goods, clothing, and in fact, their all. The most costly residence caught in the destructive path of the storm was the De Pauw homestead, an old and substantial structure built of brick on a stone foundation, two stories and an attic in height. This structure was largely demolished, one inmate killed and several others injured. Mr. VanVreedenburg, one of the occupants of this residence, states that he and his mother were in a room on the second floor when they heard the approach of the storm, the sound of which he describes as resembling a sawmill buzzing in a low key. Almost immediately the storm struck the house and the next thing he realized was that he and his mother were in the midst of a mass of débris. The windows of the house were all gone, and a partition wall pushed in. Both suffered injury, but neither was seriously hurt. The room in which they were was located on the windward side of the building, and the instant the storm struck, the windows were all blown away. The stairway leading to the first floor was torn down. Many large and beautiful old shade trees and other trees at the De Pauw homestead were destroyed, a number being uprooted and others snapped off at the trunk.

The storm began at 3:08 p. m. and lasted only about five minutes. New Albany, Ind., and surroundings are plainly visible from the windows of the Weather Bureau office in Louisville, Ky., the scene of the storm being about 4½ miles in a northwest line from the office. The approach of the storm was viewed from the office windows, but the scene was soon cut off by heavy sheets of rain. The storm from this distance had the appearance only of an ordinary thunderstorm, with a dark-green background and attended by dark-green clouds. The storm was also attended by heavy downpours of rain, but there were comparatively little thunder and lightning. No tornado or funnel-shaped cloud was observed; but this could readily have been hidden by the blanket of rain which soon blotted out the view. There is plenty of evidence, however, both in the enormous force exerted by the storm, and in the deposit of the débris in its path, that the storm was tornadic. Also the manner in which some houses not entirely destroyed were twisted off their foundations, together with the twisting of trees, shows tornadic force. The center line of the destructive forces of the storm was plainly traced; also destruction seems to have been wrought more from a south direction than from a north; that is, it appears in many instances that the wind force from the south side was greater than from the north side,

although this was not universally the case, as, for example, one house was moved bodily from its foundation 3 to 6 feet in a southeasterly direction.

The storm obviously developed in connection with the passage eastward of a long trough of low pressure in which there was a well-defined windshift line. The 8 a. m. (75th meridian time) weather map of March 23 showed an area of low pressure centered near Lake Michigan, and which extended in a trough from this center southward practically to eastern Texas. The windshift line of this trough at that time would extend from Green Bay, Wis., southwestward through St. Louis to near Houston, Tex. With the eastward movement of the general storm, the 8 p. m. map (75th meridian time) shows this windshift line then would extend from about Sault Ste. Marie, Mich., through Cleveland, Ohio, and on through Kentucky east of Lexington to near Atlanta, Ga. Thus the line evidently must have passed over Louisville about 3 p. m.

Low scuds of clouds were observed at Louisville in the early morning, driving rapidly from the southwest. Other clouds above this layer were driving rapidly from the southeast; while still above this layer were other clouds apparently moving from the west. These cloud formations and movements clearly evidenced strong transverse and counter currents in the air as early as 7 a. m. Strong south winds, velocity ranging between 30 and 35 miles per hour, prevailed at Louisville from the early morning until 3:08 p. m., when they shifted suddenly to west and attained a velocity of 52 miles per hour from that direction for a period of 5 minutes, from 3:08 to 3:13 p. m., the extreme velocity for 1 mile being at the rate of 60 miles per hour. Excessive rain, 0.73 inch, fell from 3:08 p. m. to 3:41 p. m., during which time there were two very heavy dashes, (1) 0.32 inch from 3:08 to 3:20 p. m., and (2) 0.20 inch from 3:36 to 3:41 p. m. The barometer fell steadily about 0.30 inch between midnight and 10 a. m., and rapidly, 0.45 inch, from 10 a. m. to 3 p. m. The sudden drop at the time of the tornado was 0.10 inch, followed by an immediate rise of 0.20 inch, the temperature falling at the same time from 69° to 58°. No damage was done at Louisville, although quite a thundersquall was experienced.

I am submitting herewith a copy of the barograph trace made at the Louisville, Ky., station, located 4½ miles southeast of the tornado path; also a copy of the

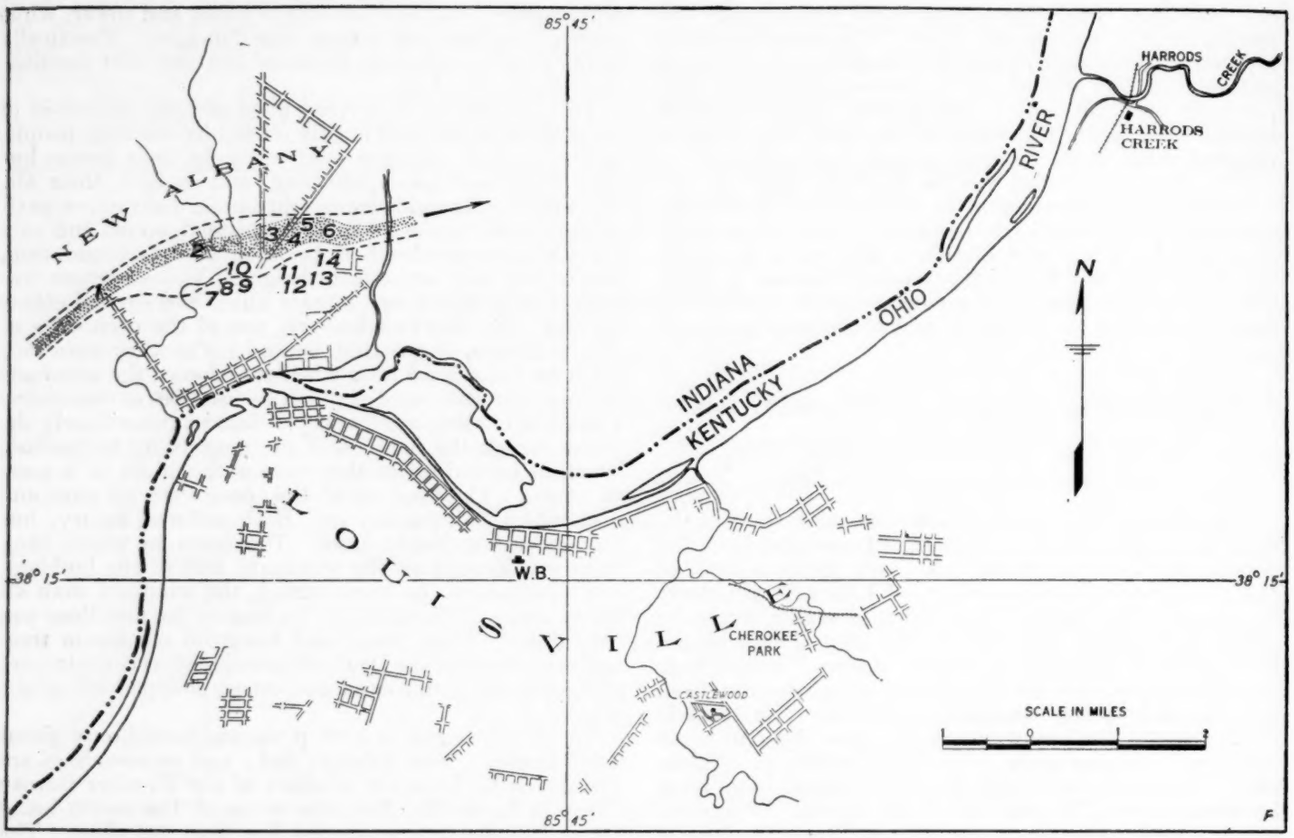

FIG. 1.—Map of the vicinity of New Albany, Ind., showing path of the tornado of March 23, 1917. (Compiled by Weather Bureau from U. S. Geological Survey map of Jefferson County, Ky., and a plat of New Albany, Ind.)

Path of total destruction is stippled; lateral zones of great damage are delimited by dash lines; numbers mark isolated localities of extensive damage and refer as follows:

1. Silver Hills.
2. Olden Street School.
3. Kahler Wood Specialties.
4. Public School.
5. Miss de Pauw's residence.
6. Cemetery.
7. International Harvester Co.
8. J. F. Tegart Public Warehouse.
9. Cemetery.
10. Jacobson's Kitchen Furniture Manufacturing Co.
11. Woolen mills.
12. Hosiery mills.
13. Shelby Street School.
14. Soldiers' Cemetery.

W. B. Weather Bureau office in Louisville, Ky.

→ Direction of movement.

barograph trace made at my residence at Castelwood, Ky., located about 3 miles southeast of the Louisville station, that is, about 7½ miles southeast of the tornado belt (see fig. 1 and 2).

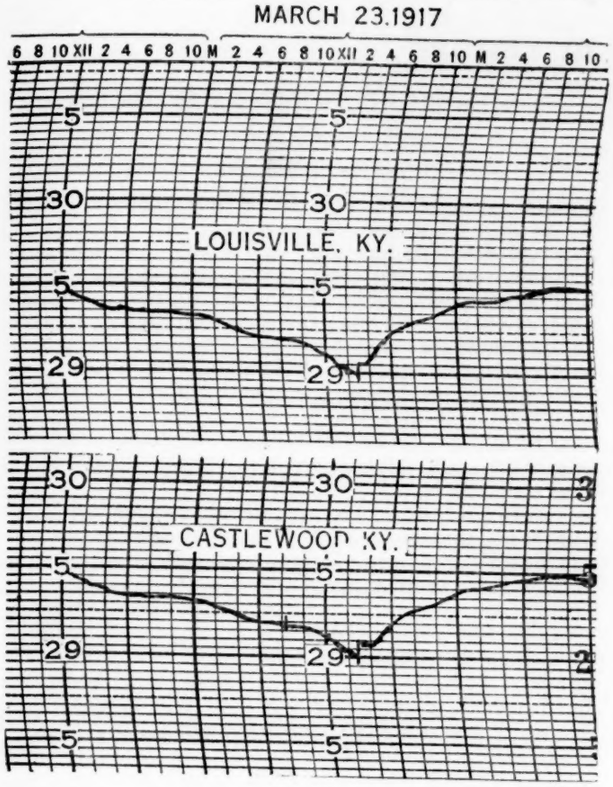

FIG. 2.—Barograms recorded by Richard barographs at the Louisville office and at Castlewood, Ky., accompanying the New Albany tornado (station pressures; 90th meridian time), showing effect of pressure changes.

Among the great mass of destruction, the following seems to call for special mention: The Olden Street School for colored children, in which 40 teachers and children were gathered, was entirely destroyed, all the inmates injured, 12 being killed.

Kahler's Wood Specialties Manufacturing plant was completely destroyed, 8 men were killed and of the other occupants all but two were seriously injured.

One entire family, consisting of five persons, perished, the father Edward Johns being decapitated and horribly mangled.

A painter, Clarence Moss, while working on a house was killed by flying timbers, his head being severed from his body.

Of another family of six, all but the father, who was away at the time, perished. The mother and two children were killed in the house when it was demolished, while two small children who were in the front yard when the storm struck were caught up and carried away, their bodies being found two squares from the ruins of their home. The body of another young girl was found about a quarter of a mile from her home where she was known to have been when the storm struck. Her home was absolutely wiped out, not a piece being left standing. Charles Newkirk had a fence paling driven through his body, but lived for a few days. Mrs. Alice Hartley had her eyes put out by flying glass. The money damage is estimated between one and one and a half million dollars.

FISH KILLED BY THE COLD WAVE OF FEBRUARY 2-4, 1917, IN FLORIDA.

By RUY H. FINCH, Assistant.

[Dated: Seismological Investigations, Weather Bureau, Apr. 20, 1917.]

An interesting occasional and but little known effect of cold waves over shallow waters of the Tropics and sub-Tropics is the killing of thousands of fish. Many species are so chilled as to be rendered helpless and are either killed directly by drowning or are washed ashore in a comatose state. This phenomenon is locally known as "freezing" of fish, though the temperature of the water may be several degrees above its freezing point.

This killing of fish by chilling is not confined entirely to tropical and subtropical waters, for great quantities are sometimes killed along the Atlantic coast as far north as New England during very severe cold waves, and it is an occasional fall and winter accompaniment of the Texas norther.[1] Somewhat similar effects have been reported from South Africa.[2] There, however, the cooling of the water seems to be due to variations in position of cold ocean currents rather than to cold air temperatures.

This "freezing" phenomenon was observed in Florida during the cold wave of February 2–4, 1917, along most of the coast line, both Atlantic and Gulf, though in the northernmost regions affected mortality was confined chiefly to shell fish and the smaller free swimming varieties.

The cooling of the water is directly due to contact with cold air,[3] hence the great expanses of shallow water surrounding the Florida Keys and in the numerous shallow bays, but little affected by tides, are excellent exposures for rapid cooling. The temperature fell decidedly during the night of February 2–3, and air temperatures at freezing were reached over most of the State except the Florida Keys, an air minimum of 43.5° being reached at Key West.

The greatest "freeze" of fish on record in Florida is that of January 12, 1886, when the lowest temperature ever observed in Key West, 41°, was reached. The countless thousands of fish washed up during this "freeze" were used as fertilizer at many places. Residents near the shore went fishing by strolling along the beach with a basket under the arm and picked up selected varieties of "frozen" fish as fast as they were washed ashore.

As a rule, gregarious species were not affected as much as those of solitary habits, for the former have the tendency to leave the cold coastal waters and go out to sea. Along the east coast many varieties availed themselves of the proximity of the Gulf Stream and went out to it, where they remained until the return of normal temperatures.

In the neighborhood of Cedar Keys, as far north as marked mortality occurred, the majority of the species observed to have been killed were small fish, 2 to 3 inches in length, crabs, small shrimp, sand worms, etc. In the vicinity of Tampa some mullet, grunts, and jackfish were killed. Farther south more and larger varieties were affected. In the neighborhood of Key West large barracuda and even sharks were thrown out upon the beaches; conchs and shellfish succumbed by the thousand; and one octopus of moderate size was noticed apparently dead. A great many fish were numbed by the cold, and, if they were not washed ashore, came out all right as soon as the

[1] Report of U. S. Fish Commission, 1886, pp. 68–72.
[2] Union of South Africa, Province of the Cape of Good Hope. Marine Biological Report No. 2, 1914, pp. 18–34.
[3] The chilling of the water must also be due, in part at least, to conduction to the chilled ground but chiefly to direct radiation into the cold, dry, transparent air brought down to these warm latitudes by the unusual weather conditions.—C. A., jr.

weather warmed up. Several communities employed laborers to bury the tons of dead fish in order to minimize the stench that would arise from their decay.

The cold wave was not without some economic benefits. According to the findings of Mr. Ernest Danglade, of the U. S. Bureau of Fisheries, who was working in the vicinity of Cedar Keys and Port Inglis at the time of the cold spell, a parasite that had been doing much damage to oysters was almost completely eradicated by the cold, while the oysters themselves were harmed but little.

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR APRIL, 1917.

EDWARD H. BOWIE, Supervising Forecaster.

[Dated: Weather Bureau, Washington, D. C., May 22, 1917.]

During the month of April, over the Aleutian Islands and Bering Sea, the pressure was abnormally high on all days except from the 8th to 12th and the 14th to 18th, when normal or subnormal pressures were recorded. The pressure was also abnormally high over central and southern Alaska except on the 4th and 5th, and 9th to 12th. In the vicinity of the Hawaiian Islands the fluctuations in pressure were not decided; readings slightly above normal were recorded during the month, except from the 11th to 14th and 9th to 21st, when the pressure was relatively low. The only important depression in the barometer over these islands occurred on the 26th, 27th, and 28th.

Over the western portion of the Atlantic Ocean, as shown by the reports from St. Johns, Newfoundland, and Hamilton, Bermuda, the pressure was low during the month, although pressure above the normal was recorded from the 16th on to the 22d.

In the United States the month showed a greater number of HIGHS and LOWS than is normally expected; 14 well-defined LOWS and 8 HIGHS were charted. Of the LOWS, 2 made their first appearance over Alaska, 3 off the North Pacific coast, 3 over California, and 6 were of the Colorado type. Of the HIGHS, 3 made their first appearance over Alaska, 3 off the North Pacific coast, 1 over the northern Rocky Mountains region, and 3 north of the Great Lakes. As might be inferred from the number of HIGHS and LOWS that were charted, the month was one of marked variability in temperature and frequent changes from dry weather to days with precipitation. Moreover, many of the LOWS followed tracks that reached to low latitudes and consequently were attended by general precipitation, while 6 of the 10 HIGHS charted were of continental origin, being first observed in southern Canada, and brought with them unseasonably low temperatures. This was particularly true over the northern and western States.

WASHINGTON DISTRICT.

April, 1917, opened with a disturbance over the lower Mississippi Valley, whence it moved rapidly northeastward, being central the morning of the 2d over the lower Lakes, and on the 3d over the St. Lawrence Valley. This disturbance was attended by general rains and thunderstorms in the Great Central Valleys and the Gulf States, and by strong shifting winds on the middle Atlantic and New England coasts. On the morning of the 1st when the storm was central over Arkansas, small-craft warnings were displayed on the east Gulf coast, and on the 2d storm warnings were displayed on the Atlantic coast at and north of Delaware Breakwater. The highest velocities reached during the 3d were 38 miles at Baltimore and 44 miles at New York City. Following this disturbance the pressure rose rapidly, and frost warnings were required for the Ohio Valley and Tennessee. Another storm area formed over the southern Plains States on the 3d, and by the morning of the 4th its center had moved eastward to northwestern Arkansas, and on the morning of the 5th its center was over Indiana, where the pressure was below 29.45 inches. This storm at this time had already been attended by general rains and thunderstorms in the South and Middle Atlantic States, and the Mississippi and Ohio Valleys, and by snow in the Upper Lakes region. In expectation that this storm would further increase in intensity, storm warnings were displayed the morning of the 5th on the Atlantic coast from Jacksonville, Fla., to Eastport, Me. On the 6th the center of this disturbance was over eastern Pennsylvania and strong winds had already prevailed along the entire Atlantic coast in the area where storm warnings were displayed. Snow continued along the northern international boundary and in the upper Ohio Valley, and there were general rains throughout the Atlantic States. The center of this storm passed northeastward off the New England coast during the 7th, but the gales on the north Atlantic coast did not subside until the night of that date.

Another storm made its appearance over Colorado on April 5, passed eastward to the middle Mississippi Valley on the 7th, and on the morning of the 8th its center was over Tennessee, from which position it moved rapidly eastward, reached North Carolina by 8 p. m. of that day, and then turned northward, increasing in intensity and attended by shifting gales along the Atlantic coast from North Carolina northward. It also caused rains and snows in the middle Mississippi and Ohio Valleys, and in the Middle Atlantic and New England States. When the center of this disturbance was over North Carolina, on April 8, storm warnings were ordered displayed on the Atlantic coast from Cape Hatteras to Cape Cod, and on the morning of the 9th the display was extended northward to Eastport, Me. The warnings were timely and fully verified.

After this storm the pressure rose decidedly and the weather became much colder and comparatively quiet generally east of the Mississippi River; it was necessary to issue frost warnings for the Ohio Valley, Tennessee, and the east Gulf and South Atlantic States, except the Florida Peninsula, and warnings of freezing temperatures for the Middle Atlantic States.

Storm warnings were not again required until the morning of April 25, when they were ordered for the Great Lakes with the exception of extreme western Lake Superior and southern Lake Michigan. The storm under consideration (— on Chart III) was central, the morning of the 25th, over Illinois, whence it advanced northeastward, increasing in intensity, and on the morning of the 26th its center was over eastern Lake Superior. This disturbance was attended by rains, snows, and shifting gales over practically the entire Lakes Region. A disturbance formed during the 28th over the western Plateau Region, advanced eastward, and on the morning of the 30th its center was over Arkansas. This disturbance developed rapidly in intensity during the succeeding 12 hours, and at 3 p. m. of that date the necessary storm

warnings were displayed on Lake Michigan; at 10 p. m. on the same day, the warnings were extended over Lakes Huron, Erie, and Ontario. This disturbance moved northeastward gaining greatly in intensity, and was attended by gales on the Great Lakes and by severe local thunderstorms in the lower Ohio Valley.

WARNINGS FROM OTHER DISTRICTS.

Chicago district.—Unseasonably low temperatures prevailed throughout this forecast district during April, so that vegetation was not sufficiently advanced to require frost warnings until after the 20th, except in southern Illinois, Missouri, and extreme eastern Kansas. Warnings were issued for portions of these States on April 4, 5, 7, 8, 12, 13, and 21. The warnings were fully verified, as a rule. Between the 20th and the end of the month warnings were required as far north as Nebraska, Iowa, and extreme southern Wisconsin.

On the 25th a disturbance was centered over northern Illinois, moving northeastward, and was followed by an area of high pressure and freezing temperature from the Northwest. Frost warnings were issued for portions of Illinois, Iowa and Missouri, and were only partially verified. No further warnings were required until the 30th when a disturbance was central over southern Missouri, with rising pressure and abnormally cold weather to the west and northwest. Accordingly, frost warnings were issued for Missouri, Kansas, Nebraska, and eastern Iowa, and were fully verified, except in portions of eastern Missouri.—*Chas. L. Mitchell, Assistant Forecaster.*

New Orleans district.—Frost warnings were issued as follows: On April 1 to western Texas, frost south, freezing north; to Oklahoma, heavy frost, probably freezing; to Arkansas, frost, probably heavy in northwest portion; to northeastern Texas and northern Louisiana, frost. On April 2 to Arkansas, Oklahoma, and the northeastern portion of eastern Texas and northern Louisiana. On April 4 to western Arkansas, southeastern Oklahoma, and northeastern Texas. On April 5 to Arkansas and northern Louisiana. On April 7 to Oklahoma, frost in southern, freezing in northern portion; to western Texas, frost except in southeastern portion, freezing in the Panhandle; to eastern Texas, frost in northwest portion. On April 8 to Louisiana, frost in interior; to Arkansas, heavy frost in the south, freezing in the north; to Oklahoma, freezing; to western Texas, frost in south, freezing in north; to eastern Texas, frost in interior, heavy frost in north. On the 12th to Oklahoma and the northern portion of Texas. On the 13th to Arkansas. On the 14th to Arkansas and northern Louisiana; on the 20th to Arkansas, Oklahoma, and extreme northern portion of Texas; on the 25th to the Texas Panhandle and northern Oklahoma; on April 30 to Oklahoma, northwestern Arkansas, and the extreme northern portion of Texas. All of the foregoing warnings were verified, except those issued on the 14th and 25th when weather disturbances moved somewhat more rapidly than was anticipated, causing cloudiness over the area for which frost was forecast.

Fire-weather warnings were issued on April 4, 6, 27, and 30, and were justified.

Storm warnings were ordered for the Texas coast on April 27 and storm winds occurred at some stations.—*I. M. Cline, District Forecaster.*

Denver district.—April, 1917, was marked by two stormy periods during which rain or snow fell over a large part of the district, greatly benefiting agricultural interests.

A warning of frost for the vicinity of Phoenix was issued on the morning of April 1 because an anticyclonic area on the middle Pacific coast was expected to spread eastward to Arizona. Frost occurred as forecast.

Fire-weather warnings were issued on the evening of the 2d for northern Arizona and southern New Mexico on account of falling pressure. The wind velocity at Roswell, N. Mex., at the evening observation on the 3d was 32 miles per hour, while in western Arizona it attained a velocity of 52 miles per hour. On the morning of the 3d an anticyclonic area, attended by low temperature, was moving eastward over the northern Plateau region and frost warnings were issued for western Colorado, central and southeast Arizona and northwestern Utah, and warnings of heavy frost or freezing temperature were distributed for southeast New Mexico in the evening of the 3d. Freezing temperature or frost prevailed on the morning of the 4th, except in southern Arizona. Frost or freezing temperature warnings were again issued for southeast New Mexico on the morning of the 4th and a killing frost with a temperature of 28° occurred at Roswell, N. Mex., the following morning. On the morning of the 6th an anticyclonic area was moving eastward across the northern Rocky Mountain region and frost was forecast for northern Utah. Frost occurred the following morning at Salt Lake City, with a temperature of 34°. On the morning of the 7th the HIGH had extended southward into Colorado and freezing temperature was forecast for southeastern New Mexico. These warnings were repeated on the morning of the 8th and were justified.

Fire-weather warnings for Arizona and southwest Utah were issued on the evening of the 8th and for New Mexico on the evening of the 9th. Moderately high winds occurred in localities. Moderately high pressure prevailed in the district on the morning of the 12th, with an anticyclonic area over northern California, and warnings of frost or freezing temperature were issued for southeast New Mexico, frost for south-central Arizona, and heavy frost for northern Utah. Heavy frost, with a temperature of 34° occurred at Salt Lake City. In the southern portion of the district, however, falling pressure prevented the expected fall in temperature. Frost warnings for northern Utah were repeated on the 13th and frost occurred the following morning followed by rising temperature. Fire-weather warnings for Utah, Arizona, and New Mexico were issued on the evening of the 14th as a storm of marked character had developed over Utah. A velocity of 40 miles per hour occurred at Santa Fe and 34 miles at El Paso. Moderately high winds occurred locally in other parts of the district. On the morning of the 15th the center of the storm was over western Colorado and warnings of heavy frost for central Arizona and freezing temperature or heavy frost for Utah and northwest Colorado were issued. A killing frost with a temperature of 28° occurred at Salt Lake City, but the development of a secondary depression over Utah was attended by precipitation in Arizona and southern Utah and cloudy skies in western Colorado.

On the morning of April 19 an anticyclonic area was spreading eastward over the Plateau Region and warnings of freezing temperature or heavy frost were issued for Colorado, eastern New Mexico, northern Utah, and southeast Arizona. Freezing temperatures occurred in practically the entire area covered by the warning. As the anticyclonic area had overspread the district with no decrease in intensity, freezing temperature warnings were repeated on the 20th for Colorado and eastern New

Mexico. Freezing temperatures again occurred in Colorado and temperatures of 34 to 36° in eastern New Mexico. An area of high pressure was over western Montana on the morning of the 24th and freezing temperature or frost warnings were issued for Colorado and northwestern Utah. The rapid eastward movement of the anticyclonic area and the development of cyclonic conditions on the western slope was attended by cloudy weather, and although the temperature fell 10 to 20° in central Colorado and slightly at Salt Lake City, the freezing point was not reached except in localities in northeastern Colorado. A disturbance was developing over the Plateau Region on the 25th and fire-weather warnings were issued for localities in southern New Mexico, Arizona, and Utah. Wind velocities of 40 miles per hour occurred at Modena, 46 miles at El Paso, and over 30 miles in northern Arizona. Warnings of freezing temperature were issued for Colorado and northern and western Utah on the morning of the 27th, and for Colorado, Utah, and eastern New Mexico on the 28th. Freezing temperatures occurred throughout Colorado and generally in Utah. At Denver 24° was recorded.—*Frederick W. Brist, Assistant Forecaster.*

Portland, Oreg., district.—Owing to prevailing high pressure over northern Alaska, LOWS from the Pacific Ocean entered the United States farther south than usual, and no well-developed HIGHS moved from the California coast north to Washington and thence east. Such pressure conditions caused a preponderance of cold, and wet weather in this district. The cold weather was largely due to low afternoon temperatures rather than to cold nights. Warnings for light frost were issued on no less than 12 days for portions of the district and for the most part they were verified; but no damaging frosts occurred in localities where vegetation was far enough advanced to be injured by them.

Storm warnings were ordered at all stations twice, and at the entrances to the Strait of Juan de Fuca, Strait of Georgia, and the Columbia River on two occasions. Two were partly verified and the other two were failures. Those that were failures had been ordered because of threatening conditions which could not be covered after dark by small-craft warnings, and the displays were ordered down early the next morning. Small-craft warnings were ordered on 4 days and they were either partly or fully verified.

A live-stock warning was issued to all stations on April 25 to cover a 3-day period of wet weather, and it was fully verified. Live-stock warnings if issued on the 13th would have been of benefit to stockmen. The bad weather following this date—weather due to the development of stormy conditions over the district instead of to their moving in from the west—was not foreseen sufficiently far enough in advance of its occurrence to enable a warning to be issued. Such developments are generally indicated by the pressure-change map, but in this case it apparently failed to give sufficient information to justify the issuing of a warning.

The whole of April with its low temperatures and wet weather was hard on stock, which, besides being exposed to inclement weather, was underfed in consequence of a shortage of hay and of poor pasturage which made scarcely any growth. At no time during the month was it safe to advise the stockmen that a period of good weather would prevail for more than 36 hours ahead, while ordinarily in April several days of dry sunshiny weather occur when the Pacific HIGHS follow their normal track, and move up the coast from California to Washington, and thence eastward. Stockmen generally kept their herds close to the home feeding grounds for fear they might wander too far in search of feed, and thereby not be able to reach shelter should stormy weather set in.—*E. A. Beals, District Forecaster.*

San Francisco district.—No general storms occurred in this district during April, 1917, and only a few periods of showery weather when the heaviest precipitation was confined to the mountain regions. More than the usual number of frosts occurred, and the one on the morning of the 16th caused some damage to peaches and apricots in portions of the Sacramento valley. Warnings were issued on the morning of the 15th.

Southeast storm warnings were issued for the northern coast on the 13th, but verifying velocities did not occur. Southwest warnings were issued along the southern coast on the 26th, and were verified. The month as a whole was dry and until the last week the temperatures were generally below the normal.—*G. H. Willson, District Forecaster.*

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, APRIL, 1917.

By ALFRED J. HENRY, Professor in Charge.

[Dated: River and Flood Division, May 26, 1917.]

Numerous local floods of small intensity occurred in the rivers of the South Atlantic and East Gulf States, the details of which will be found in the tables which accompany this report. The general floods in the Tennessee, the lower Ohio, and the Mississippi below Cairo had their beginning in the previous month; the statistical record for April is given in the accompanying tables.

North Atlantic drainage.—Although the presence of a snow cover in northern New England is always more or less of a flood menace in the spring months, the snow cover of 1916–17 passed away without causing floods of consequence.

South Atlantic and East Gulf drainage.—Numerous local floods occurred in many of the rivers of the section. The lower Santee was in flood continuously from March 24 to April 23, but in general the remaining floods were of short duration and the crests were only a few feet above flood stage.

The Black Warrior River overflowed its banks below Tuscaloosa, Ala., and there was also an overflow of the lowlands along the Tombigbee River below Demopolis, Ala.

These were the only cases of serious overflow in the South that occurred during the month. At the end of the month all of the rivers were well within their banks.

Great Lakes drainage.—Local floods occurred in the rivers of Michigan, northern Indiana, and northern Ohio, as shown in Table 3.

Mississippi drainage.—The spring rise in the main stream north of Cairo did not pass much beyond freshet stages. The flood stage was passed at St. Paul, Minn., Hannibal and Louisiana, Mo., and Grafton, Ill., only. The flood at the last-named places was due to the occurrence of heavy rains in Iowa, Missouri, and Illinois at a time when the run-off from melting snow in Wisconsin and Minnesota had reached that stretch of the river. In the lower stretch of the river—New Madrid, Mo., to New Orleans, La.—the river was in flood for varying periods due to the flood waters contributed by eastern tributaries during the previous month. At New Orleans the river passed below flood stage, 18 feet, on the last day of the month, having been in flood only two days. It was still in flood, however. in the stretch—Arkansas City, Ark., and Donaldsonville, La. In general, the flood of 1917 in the lower Mississippi was of little intensity and of relatively short duration.

Eastern tributaries of the Mississippi.—The flood of the preceding month continued in the lower stretches of the Ohio until the 17th, a crest stage of 50.1 feet being reached at Cairo on the 4th. At the close of the month all important eastern tributaries of the Mississippi were falling.

Western tributaries of the Mississippi.—The breaking of an ice gorge in the Missouri below Bismarck, N. Dak., on the 9th released a considerable quantity of water that overflowed the lowlands between Springfield and Running Water, S. Dak., on the 13th, but without causing serious damage. This flood wave passed downstream, reaching St. Joseph, Mo., on the 18th at a stage only a few tenths of a foot above the flood level. Farther downstream the flood level was closely approached but not reached.

Floods did not occur in any of the remaining western tributaries of the Mississippi.

Colorado drainage.—Heavy rains over the headwaters of the Agua Fria and Verde Rivers of Arizona on the 16th and 17th caused a freshet in the lower Gila and also in the Colorado.

The run-off from melting snow at moderate elevations in Utah, Colorado, and Wyoming was not sufficient to cause floods in the lower Colorado.

The loss by flood during April, 1917, was approximately as follows:

District.	Tangible property, bridges, etc.	Crops.		Movable property live stock, etc.	Suspension of business.	Area overflowed.
		In hand.	Prospective.			
						Acres.
Mobile, Ala.				$200	$2,600	
Montgomery, Ala.	$3,000	$550	$72,000	900	3,650	11,240
Columbia, S. C.	400	4,000	17,200	1,675	110	1,240
Macon, Ga.					5,000	
Cairo, Ill.	800		28,000	100	15,000	950
Total losses	4,200	4,550	117,200	2,875	26,360	13,430

Estimated saving by the warnings, $167,700.

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

TABLE 1.—*Floods in North Atlantic drainage during April, 1917.*

River.	Station.	Flood stage.	Above flood stages.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Penobscot	West Enfield, Me.	14			13.4	5
Connecticut	Wells River, Vt.	32			27.4	4
Do.	White River Junction, Vt.	13	3	8	14.4	4
Do.	Hartford, Conn.	16	24	24	16.1	24
White	White River Junction, Vt.	15	22	25	16.0	23
Hudson	Troy, N. Y.	15			14.6	3
Delaware East Branch.	Fishs Eddy, N. Y.	10	2	2	10.8	2
Chenango	Sherburne, N. Y.	8			7.8	2

TABLE 2.—*Floods in South Atlantic and East Gulf drainage during April, 1917.*

River.	Station.	Flood stage.	Above flood stages.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Roanoke	Weldon, N. C.	30	8	8	33.2	8
Staunton	Randolph, Va.	21			20.3	7
Tar	Rocky Mount, N. C.	9			8.1	8
Do	Tarboro, N. C.	18	11	12	18.2	11
Do	Greenville, N. C.	13	10	15	14.4	12,13
Neuse	Neuse, N. C.	14	7	8	14.1	7,8
Do	Smithfield, N. C.	13	7	12	16.4	10
Cape Fear	Elizabethtown, N. C.	22	8	12	25.6	11
Do	Fayetteville, N. C.	35			32.5	10
Pee Dee	Cheraw, S. C.	27			24.8	10
Santee	Rimini, S. C.	12	1	20	16.9	1
Do	Ferguson, S. C.	12	1	23	14.0	12
Wateree	Camden, S. C.	24	6	7	26.3	6
Broad (of South Carolina)	Blairs, S. C.	15	6	6	15.0	6
Broad (of Georgia)	Carlton, Ga.	11			10.6	6
Saluda	Pelzer, S. C.	7	5	5	7.0	5
Do	Chappells, S. C.	14	6	7	15.0	7
Oconee	Milledgeville, Ga.	22	6	6	25.4	6
Do	Dublin, Ga.	22			18.7	9
Ocmulgee	Abbeville, Ga.	11	1	6	14.4	2
			10	15	14.0	11
Do	Macon, Ga.	18	6	6	19.5	6
Do	Lumber City, Ga.	15	6	6	15.2	6
Chattahoochee	Norcross, Ga.	16			11.6	6
Do	Alaga, Ala.	30			28.3	8
Alabama	Montgomery, Ala.	35	6	9	37.9	7
Do	Selma, Ala.	35	1	12	42.3	1
Coosa	Lock No. 4, Ala.	17	1	9	19.4	5
Etowah	Canton, Ga.	11			10.7	5
Cahaba	Centerville, Ala.	25	5	5	25.2	5
Tombigbee	Aberdeen, Miss.	33			30.0	8
Black Warrior	Tuscaloosa, Ala.	46	5	9	56.3	7
Pearl	Edinburg, Miss.	21			20.0	8
Do	Jackson, Miss.	20	3	19	26.5	10,11

TABLE 3.—*Floods in Great Lakes drainage during April, 1917.*

River.	Station.	Flood stage.	Above flood stages.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Maumee	Fort Wayne, Ind.	15	2	8	18.6	6
Sandusky	Upper Sandusky, Ohio	13			12.0	7
Saginaw	Saginaw, Mich.	19			18.1	8,9
Cass	Vassar, Mich.	14			13.7	6,7
Grand	Grand Ledge, Mich.	6	7	9	7.0	7
Do	East Lansing, Mich.	8	7	8	9.4	7

TABLE 4.—*Floods in Ohio River and tributaries during April, 1917.*

River.	Station.	Flood stage.	Above flood stages.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Ohio	Henderson, Ky.	33	1	7	36.3	1
Do	Evansville, Ind.	35	1	7	38.1	1
Do	Mount Vernon, Ind.	35	1	8	38.5	1
Do	Shawneetown, Ill.	35	1	16	41.0	1
Do	Paducah, Ky.	43	1	11	45.7	2
Do	Cairo, Ill.	45	1	17	50.1	4,5
Tuscarawas	Norris Point, Ohio	8	7	8	8.6	7
Do	Coshocton, Ohio	8	7	8	8.6	7
Walhonding	Walhonding, Ohio	8	6	7	9.0	7
Hocking	Athens, Ohio	17			16.0	7
Scioto	Circleville, Ohio	7	7	8	10.0	7
Olentangy	Delaware, Ohio	9			8.4	6
White	Decker, Ind.	18	9	12	18.3	10,11
Green	Lock No. 2, Ky.	34	1	16	40.4	10,11
Do	Lock No. 4, Ky.	33	3	10	39.1	8
Do	Lock No. 6, Ky.	30			29.6	4
Wabash	Mount Carmel, Ill.	15	6	15	17.8	11,12
Do	Lafayette, Ind.	11	4	9	15.6	7
Tennessee	Florence, Ala.	18	1	3	19.9	1
Do	Riverton, Ala.	32	1	10	40.7	1,2
Do	Johnsonville, Tenn.	31	1	12	36.1	6
Do	Guntersville, Ala.	31	1	2	33.4	1
Do	Decatur, Ala.	21			20.1	1
French Broad	Asheville, N. C.	4			3.8	6

TABLE 5.—*Floods in the Mississippi River and tributaries during April, 1917.*

River.	Station.	Flood stage.	Above flood stages.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Mississippi	St. Paul, Minn.	14	5	16	16.2	8
Do	La Crosse, Wis.	12			11.8	13,14
Do	Keokuk, Iowa	14			12.8	1
Do	Quincy, Ill.	14			13.9	28
Do	Hannibal, Mo.	13	22	(*)	15.0	28
Do	Louisiana, Mo.	12	23	(*)	13.7	29
Do	Grafton, Ill.	18			16.9	30
Do	New Madrid, Mo.	34	1	18	39.3	4-7
Do	Memphis, Tenn.	35	1	21	40.1	9,10
Do	Helena, Ark.	42	1	26	49.9	13
Do	Arkansas City, Ark.	42	1	(*)	52.1	17,18
Do	Greenville, Miss.	42	5	29	45.7	19-21
Do	Vicksburg, Miss.	45	3	(*)	49.8	21-24
Do	Baton Rouge, La.	35	14	(*)	37.9	30
Do	Donaldsonville, La.	28	16	(*)	29.6	26,30
Do	New Orleans, La.	18	29	30	18.1	29,30
Eastern tributaries.						
Wisconsin	Knowlton, Wis.	12			11.9	3
Illinois	Peru, Ill.	14			13.9	8
Do	Henry, Ill.	7	1	25	8.1	11
Do	Peoria, Ill.	16			15.0	1,2,5,12
Do	Beardstown, Ill.	12	1	2	13.0	1-2
Do	Pearl, Ill.	12			11.1	4
Yazoo	Swan Lake, Miss.	25	1	(*)	29.6	13-15
Do	Greenwood, Miss.	36			35.4	17-20
Do	Yazoo City, Miss.	25	5	(*)	29.6	29
Western tributaries.						
Minnesota	Fort Ripley, Minn.	10	5	7	11.4	6
St. Croix	Stillwater, Minn.	11	4	24	14.6	9
Do	do.	11	29	(*)	11.4	30
Grand	Chillicothe, Mo.	18	30	(*)	18.7	30
Meramec	Pacific, Mo.	11			10.3	30
Do	Valley Park, Mo.	14	30	30	14.6	30
Bourbeuse	Union, Mo.	10	30	(*)	11.0	30
St. Francis (Arkansas Basin)	Marked Tree, Ark.	17	16	(*)	17.3	19-24
Cottonwood	Emporia, Kans.	19			18.1	19
Petit Jean	Danville, Ark.	20	2	3	20.9	2
White	Calico Rock, Ark.	18	2	2	22.8	2
Do	Batesville, Ark.	23	2	3	28.2	3
Do	Newport, Ark.	26			24.9	6
Do	Georgetown, Ark.	22	11	14	22.2	12
Do	Clarendon, Ark.	30			27.6	20
Black	Black Rock, Ark.	14	2	24	24.6	3
Cache (Red River Basin)	Jelks, Ark.	9	16	27	9.5	20-22
Sulphur	Ringo Crossing, Tex.	20	30	(*)	22.0	30
Atchafalaya (Atchafalaya)	Simmesport, La.	41	25	(*)	41.7	30
Do	Melville, La.	37	13	(*)	39.6	30

* Continued into May, 1917.

TABLE 6.—*Floods in Missouri River and tributaries during April, 1917.*

River.	Station.	Flood stage.	Above flood stages.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Missouri	Williston, N. Dak.	24			23.3	5
Do	Bismarck, N. Dak.	14	6	9	22.2	8
Do	Blair, Nebr.	15	14	20	16.9	15
Do	Omaha, Nebr.	19			18.7	18
Do	St. Joseph, Mo.	12	18	20	12.3	19
Do	Kansas City, Mo.	22			21.6	20,21
Do	Waverly, Mo.	23			21.6	21
James	Huron, S. Dak.	9	1	21	14.4	6,7

TABLE 7.—*Floods in West Gulf and Pacific drainage, April, 1917.*

River.	Station.	Flood stage.	Above flood stages.		Crest.	
			From—	To—	Stage.	Date.
		Feet.			*Feet.*	
Trinity	Dallas, Tex.	25	29	(*)	27.5	29
Rio Grande	San Marcial, N. Mex.	14			13.8	29
Colorado (Pacific drainage)	Yuma, Ariz.	25	20	20	25.1	20
Gunnison (North Fork)	Paonia, Colo.	8			7.2	26,27
Salt	Phoenix, Ariz.	5	18	19	7.2	18
Willamette	Eugene, Oreg.	10	8	8	10.5	8
Do	Oregon City, Oreg.	10			9.3	10

* Continued into May, 1917.

RELATION BETWEEN RAINFALL AND RUN-OFF IN HILLEBRAND GLEN, NUUANU VALLEY, OAHU, HAWAII.

By ROGER C. RICE, Assistant Engineer.

[U. S. Geological Survey, Honolulu, Hawaii, Feb. 14, 1917.]

Little information is available concerning the relation between rainfall and run-off in the narrow, precipitous valleys in the Hawaiian Islands, and especially those in the vicinity of Honolulu, that are being utilized more and more as sources of municipal water supply.

The records collected in the islands by the United States Weather Bureau and the United States Geological Survey afford invaluable general information concerning rainfall, but have seldom been coordinated with records of run-off to establish factors adaptable to specific localities.

The practice of trying to solve Hawaiian Island problems by means of run-off factors derived from observations on the mainland at points differing greatly in climatic, geologic, and topographic features gives at best very unsatisfactory results. Local investigations of the relation between rainfall and run-off should be of great value in making storage estimates for future floods.

The information here presented was obtained by the water commission of the Territory of Hawaii in an intensive investigation of the rainfall and stream flow in Hillebrand Glen, Nuuanu Valley, Oahu, from May to December, 1916. At the expiration of the term of the commission, December 31, 1916, the work was continued by the Territorial Division of Hydrography, cooperating with the United States Geological Survey.

A unit of the municipal water supply of the city of Honolulu comprises four storage reservoirs—designated as reservoirs Nos. 1, 2, 3, and 4—in Nuuanu Valley, Oahu, approximately at elevations 400, 700, 800, and 1,000 feet, respectively, above sealevel (fig. 1). Reservoir No. 4 is the largest and the only one of the group that has never been filled to capacity.

Hillebrand Glen is a long, narrow, heavily forested V-shaped valley less than one-half square mile in area, lying between the western ridge of Nuuanu Valley and a southern spur from Mount Lanihuli that forms the western slope of Nuuanu Valley above reservoir No. 2 (figs. 2 and 3).

Maole Stream, in Hillebrand Glen, is formed from several small intermittent tributaries that cascade down the steep sides of the valley during periods of heavy rainfall (fig. 4). In ordinary dry weather the stream is exceedingly small, usually flowing from 25,000 to 30,000 gallons per day (0.04 to 0.05 second-foot).

The so-called "Hillebrand Glen project" of the city of Honolulu is a scheme to utilize the storm waters of Maole Stream for storage in reservoir No. 4 by constructing a diverting dam, tunnel, and lined open ditch. The increased storage will provide additional water for Nuuanu Valley and increase the power available at the municipal electric-light plant at reservoir No. 1.

So far as the furtherance of the Hillebrand Glen project was concerned, the problem of paramount importance to the commission was the determination of the amount and distribution of the seasonal stream flow of Maole Stream at the proposed point of diversion. Other considerations involved were the relation between rainfall and run-off in Hillebrand Glen and the relation between the rainfall in the glen and in Nuuanu Valley proper, where records of rainfall for 27 years had been collected by the United States Weather Bureau.

The water commission installed for its investigation a weir gaging station equipped with a Stevens continuous water-stage recorder and three raingages distributed in the glen at different elevations (fig. 1). Two of these, gages Nos. 1 and 2, were furnished by the United States Weather Bureau and were read daily. Raingage No. 3 was read weekly.

Table 1 [1] shows discharge in million gallons per day of Maole Stream, in Hillebrand Glen, from May 23, 1916, to January 31, 1917, obtained from the water-stage recorder. Tables 2 [1] and 3 [1] are weekly and monthly summaries, respectively, of the rainfall records obtained in Hillebrand

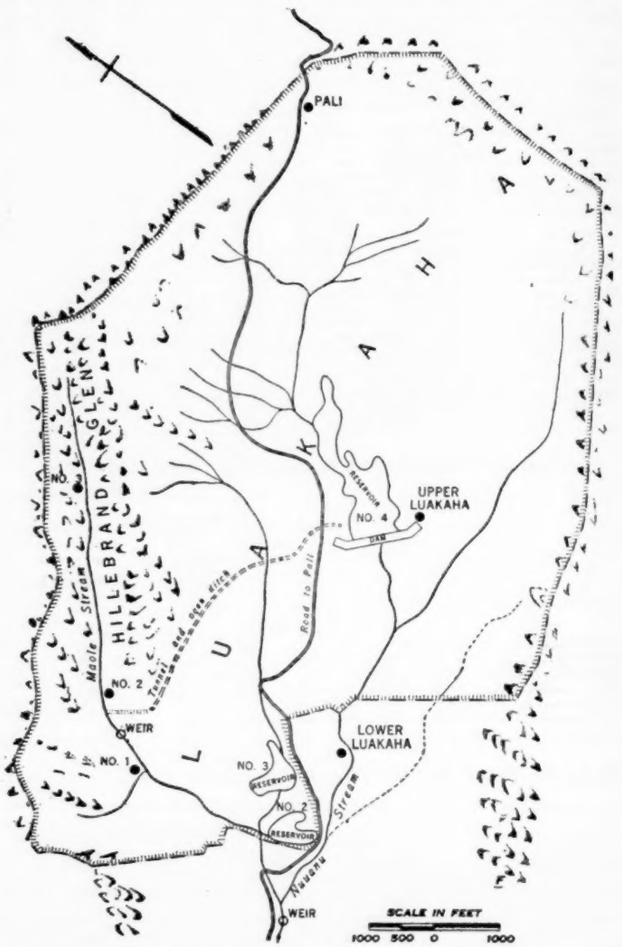

FIG. 1.—Map showing location of Hillebrand Glen in Nuuanu Valley, and location of rainfall (●) and stream gaging (○) stations.

Glen and in Nuuanu Valley proper from June to December 1916, by the water commission. Each record has been compared weekly and monthly with that for Lower Luakaha, for which a 27-year record is available. The ratios computed agree very closely and indicate that a monthly comparison of rainfall in Hillebrand Glen and Nuuanu Valley proper will give results about as satisfactory as a weekly comparison. This enables us to place more reliance on the long-time monthly comparison.

The mean rainfall and mean run-off for various well-defined storms have been compiled in Table 4,[1] which is

[1] Tables 1–5, inclusive, have been omitted, as their information seems sufficiently presented by the diagrams herewith.—EDITOR.

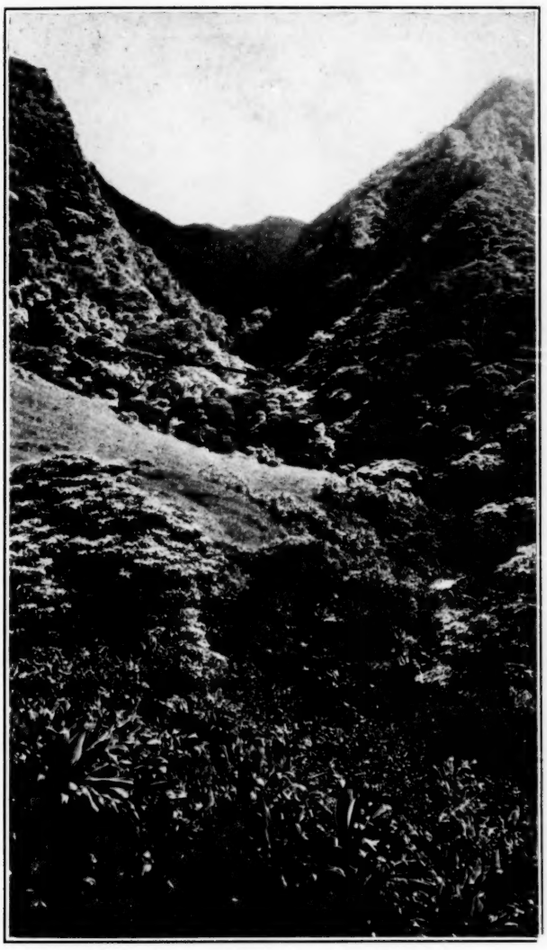

FIG. 2.—Hillebrand Glen from trail leading from Reservoir No. 2 in Nuuanu Valley. X shows location of Hillebrand Glen raingage No. 1.

FIG. 3.—General view downstream from below weir gaging station, showing Hillebrand Glen merging into Nuuanu Valley. Hillebrand Glen raingage No. 1 in foreground.

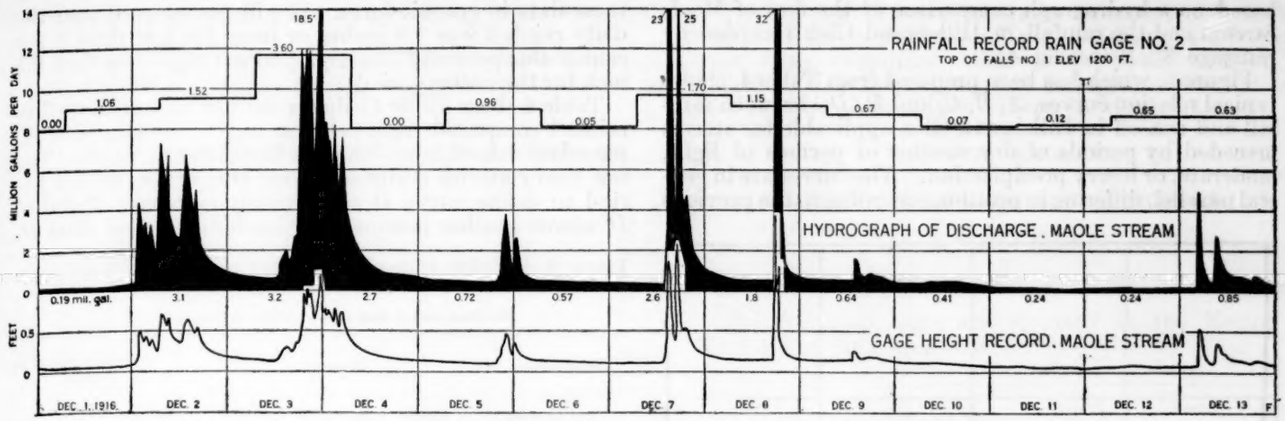

FIG. 4.—Hydrograph of typical flood periods, Maole Stream, Hillebrand Glen, December, 1916.

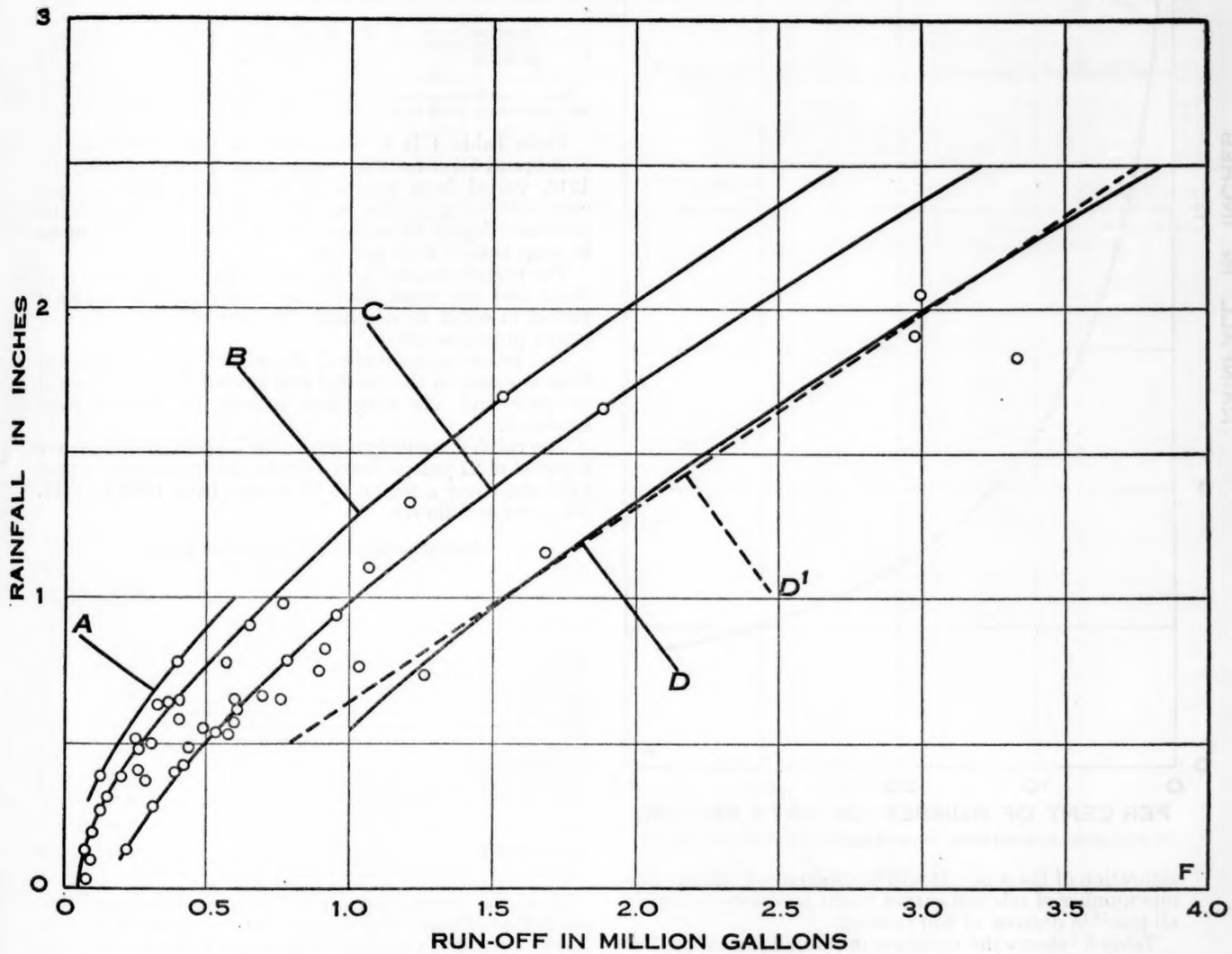

FIG. 5.—Curves of relation between rainfall and run-off, Hillebrand Glen, Nuuanu Valley. Rainfall from raingage No. 2; run-off from weir-gaging station (Stevens recorder); plotted points represent mean values for periods of several days.

A=Storms preceded by period of very dry weather;
B=Storms preceded by period of very light showers;
C=Storms preceded by period of moderate precipitation;
D, D'=Storms preceded by period of heavy precipitation.

based on a hydrograph comparison of the flow of Maole Stream and the rainfall in Hillebrand Glen recorded by raingage No. 2 (see fig. 4).

Figure 5, which has been prepared from Table 4, shows typical relation curves, *A*, *B*, *C*, and *D* (*D'*) between rainfall and run-off in Hillebrand Glen applicable for storms preceded by periods of dry weather or periods of light, moderate, or heavy precipitation. The curves are in general parallel, differing in position according to the previous

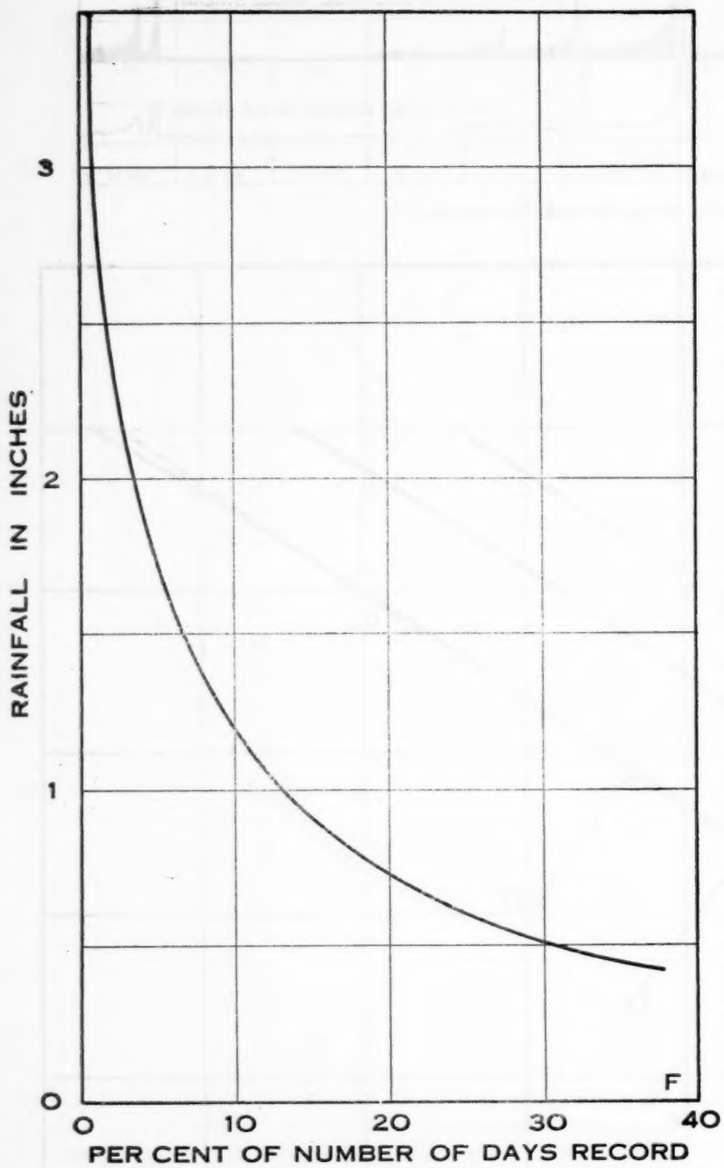

FIG. 6.—Variation in rainfall during the period June 1 to December 31, 1916 (245 days).

saturation of the soil. It will be understood that an infinite number of relation curves might be drawn to satisfy all possible degrees of soil priming.

Table 5 [1] shows the variation in rainfall from June 1 to December 31, 1916, and the number of days on which the rainfall was above stated amounts. Figure 6 shows these data in graphic form. It will be observed that the daily rainfall was 1.5 inches or more for less than 6 per cent of this period of 245 days. It averaged less than 0.5 inch for the entire period.

Table 6 (here Table 1) shows the per cent of run-off to rainfall computed from relation curves developed from records obtained from June 1 to December 31, 1916. Too few heavy storms occurred during this seven months period to define curve *D* as definitely as curves *B* and *C*. *D'* shows another possible relation for storms of class *D*.

TABLE 1.—*Relation between rainfall and run-off, Hillebrand Glen, Nuuanu Valley.*

[Drainage area at weir gaging station, 0.3 square mile.]

Precipitation.		Run-off.					Per cent of run-off to rainfall.				
Inches.	Gallons on drainage area.	A.	B.	C.	D.	D'.	A.	B.	C.	D.	D'.
		Gallons.	*Gallons.*	*Gallons.*	*Gallons.*	*Gallons.*					
½	2,600,000	190,000	270,000	500,000	950,000	780,000	7.3	10.4	19.2	36.5	30.0
1	5,210,000	600,000	720,000	1,020,000	1,550,000	1,550,000	11.5	13.8	19.6	29.8	29.8
2	10,420,000	.....	1,950,000	2,400,000	3,010,000	3,010,000	....	18.6	23.0	34.6	34.6

NOTE.—Run-off values were obtained from relation curves developed from rainfall and run-off during period June to December, 1916. (See fig. 5.)

From Table 1 it is seen that the run-off factors for Hillebrand Glen for the period June 1 to December 31, 1916, varied from practically nothing to about 35 per cent, according to the intensity of the storm and the previous degree of saturation of the soil. The mean average run-off is 20 per cent.

The period covered by this investigation has been very short and the work should be continued for a longer period in order to determine the run-off for periods of heavy precipitation.

The following estimate of the run-off from Hillebrand Glen is based on the rainfall and run-off records obtained to date and the long-time records of rainfall from Luakaha.

The rainfall monthly normals for Lower Luakaha cover a period of 27 years—from 1890 to 1916; those for Upper Luakaha cover a period of 12 years—from 1905 to 1916. They are as follows:

Normal monthly rainfall in Luakaha Valley.

	Upper Luakaha.	Lower Luakaha.
	Inches.	*Inches.*
January	11.72	9.98
February	10.06	11.88
March	12.37	13.60
April	13.90	13.02
May	15.50	11.76
June	11.36	9.95
July	11.12	10.51
August	13.60	12.21
September	14.53	11.95
October	10.49	10.81
November	14.99	13.41
December	17.18	14.59
Year	156.82	143.67
Average monthly	13.07	11.97

From the "average monthly" normals it is found that rainfall at Upper Luakaha is 109 per cent of that at Lower Luakaha, a relation which agrees closely with that obtained from weekly rainfall records for June to December, 1916 (see Table 2*). For that period the precipitation recorded at gage No. 2 in Hillebrand Glen, was 103 per cent of Lower Luakaha. The normal monthly rain-

[1] Tables 1–5, inclusive, have been omitted, as their information seems sufficiently presented by the diagrams herewith.—EDITOR.

fall for Hillebrand Glen would be $11.97 \times 1.03 = 12.33$ inches.

Actual run-off determination made by the water commission from June 1, 1916 to January 31, 1917, are as follows:

Monthly run-off in million gallons, June, 1916, to January, 1917.

1916.	
June	5.12
July	6.83
August	14.46
September	7.56
October	14.60
November	22.66
December	37.56
1917.	
January	19.92
Total, 245 days	128.68

The average daily run-off = 0.53 million gallons, or 530,000 gallons per day.

The total rainfall recorded by raingage No. 2, in Hillebrand Glen, June, 1916, to January, 1917, was 113.92 inches, or 0.46 inch per day. This quantity corresponds to a storage of $5{,}280 \times 5{,}280 \times 0.3 \times 7.48 \times \frac{0.46}{12} = 2{,}400{,}000$ gallons per day.

The per cent of actual run-off to actual rainfall for this 8-month period was $\frac{530{,}000}{2{,}400{,}000} = 22$ per cent.

This result agrees reasonably with the average ratio derived from a consideration of the rainfall–run-off relation curves (see fig. 5).

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Twenty-two per cent of 12.33 inches or 2.71 inches would be the average run-off per month, or 2.71 feet per year from Hillebrand Glen. This would amount to 170,000,000 gallons per year storage, or 465,000 gallons per day (0.46 million gallons per day).

MEAN LAKE LEVELS DURING APRIL, 1917.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., May 7, 1917.]

The following data are reported in the Notice to Mariners of the above date:

Data.	Lakes.			
	Superior.	Michigan and Huron.	Erie.*	Ontario.
Mean level during April, 1917:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sealevel at New York	602.28	580.78	572.57	246.24
Above or below—				
Mean stage of March, 1917	−0.05	+0.32	+1.04	+1.07
Mean stage of April, 1916	−0.06	+0.88	+0.12	−0.16
Average stage for April, last 10 years	+0.72	+0.63	+0.16	−0.14
Highest recorded April stage	−0.41	−2.45	−1.61	−2.19
Lowest recorded April stage	+1.74	+1.56	+1.31	+1.40
Average relation of the April level to—				
March level	±0.0	+0.2	+0.6	+0.5
May level	−0.3	−0.3	−0.4	−0.5

* April, 1916, level of Lake St. Clair was 575.21 feet.

SECTION V.—SEISMOLOGY.

SEISMOLOGICAL REPORTS FOR APRIL, 1917.

W. J. HUMPHREYS, Professor in charge.

[Dated: Weather Bureau, Washington, D. C., June 2, 1917.]

TABLE 1.—*Non-instrumental earthquake reports, April, 1917.*

Date.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		ARKANSAS.								
1917.	*H. m.*		° ′	° ′			*M. s.*			
Apr. 9	20 52	Black Rock	36 08	91 04	3	1	10		Windows trembled	S. J. Howe.
		Corning	36 23	90 33	4-5	1	5	Rumbling	Shook buildings	J. N. Crutchfield.
		Hardy	36 19	91 22	3	2	60	None		A. A. Caywood.
		Marked Tree	35 32	90 22	4-5	1		do	Furniture moved	A. R. Shearon.
		Osceola	35 43	89 54	4	1	30	do		A. P. Smith.
		Paragould	36 05	90 25	2					A. S. Snowden.
		Piggott	36 22	90 10	3	1	30			J. C. Latta.
		Pocahontas	36 15	90 55	2	1	60			Benedictine Sisters.
		St. Francis	36 25	90 06	3-4	1	30	None	Hanging lamps swayed	J. A. Reed.
		CALIFORNIA.								
2	9 00	Berkeley	37 52	122 16	3-4	1	1	Rumbling		E. F. Davis.
13	4 03	Nordhoff	34 35	119 14	5	1	2	None	Concrete tower cracked	W. H. Duncan.
		Oxnard	34 12	119 08	5	3		do	Dishes rattled	Press report.
		Santa Barbara	34 23	119 40	6	1			Most severe in recent years	Do.
		Ventura	34 17	119 17	4	2				Do.
13	12 30	Cedarville	41 32	120 08	2-3	1	60	Faint		T. H. Johnstone Co.
16	6 00	Cedarville	41 32	120 08	3	1				Do.
18	23 43	Calexico	32 41	115 30	3	2	5	Rumbling		C. N. Perry.
21	6 59	Santa Barbara	34 23	119 40	4	2				Press report.
		Ventura	34 17	119 17	4	1			Awakened people	Do.
		IDAHO.								
20	4 30	Pierson	44 03	114 48	5	3	60	Rumbling		E. E. Lanning.
		ILLINOIS.								
9	20 52	Alton	38 54	90 12	5	2		None		Mildred Brown.
		Anna	37 27	89 18	4	2	9	Rumbling		J. I. Hale.
		Cairo	37 00	89 10	4	2	14	None		U. S. Weather Bureau.
		Carbondale	37 45	89 14	4	2	25	do	Windows rattled	Prof. F. H. Colyer.
		Carlinville	39 17	89 53	5	2	30	do	Radiators swayed	Dr. J. D. Conley.
		Carterville	37 46	89 05	3	2	30	do		J. J. West.
		Chester	37 55	89 50	5	1	15	Rumbling	Buildings trembled	F. C. Kennedy.
		Danville	40 09	87 36	3	1				J. J. Lemon.
		Edwardsville	38 48	89 59	5	1		None		W. H. Morgan.
		Elizabethtown	37 27	88 12	4	1			Buildings trembled	
		Equality	37 44	88 22	3	1		None		Elizabeth Davis.
		Fairview	40 38	90 12	3-4	1		do		Abram Wilson.
		Golconda	37 22	88 31	4	2		Rumbling		J. M. Ramsey.
		Grafton	38 59	90 26	5	1			Buildings shook	W. T. Bymer.
		Greenville	38 53	89 25	5	4	30			F. P. Seawell.
		Griggsville	39 42	90 43	4	2	2	None		G. F. Kneeland.
		Harrisburg	37 45	88 34	3	1		do		Clarence Bonnell.
		Highland	38 44	89 42	5	1				Chas. Schuttinger.
		McLeansboro	38 07	88 34	3	1	2	None		A. E. Wilson.
		Mascoutah	38 30	89 48	5	1	60			Dr. R. F. Lischer.
		Morrisonville	39 31	89 30	4	1		Rumbling		J. D. Lowes.
		Nashville	38 22	89 23	4	1				E. D. Garlich.
		New Athens	38 18	89 52	4	3		None		D. M. Fullmer.
		New Burnside	37 34	88 45	3	3	30	do		Miss Mae McCabe.
		Pulaski	37 15	89 11	3-4	1				H. Reeves.
		Quincy	39 55	91 22	4	1				Press report.
		Shawneetown	37 42	88 10	4	1	10	None		E. F. Armstrong.
		Springfield	39 48	89 39	4-5	2	4	do	Shook buildings	U. S. Weather Bureau.
		Sparta	38 08	89 43	3-4	1	3			W. F. Clendenin.
		Staunton	39 01	89 50	4	3		None		Mary Whalen.
		Valmeyer	38 18	90 19	5	1	25	Faint		Chas. Schaefer.
		Vienna	37 25	88 54	5	1				C. C. Clymon.
		Waterloo	38 19	90 11	5-6	3	12	Rumbling	Shook buildings	W. E. Elfbracht.
		White Hall	39 27	90 25	5	1	30	Loud		R. B. Pearce.
9	23 35	Anna	37 27	89 18	2	1	7	None		J. I. Hale.
		Valmeyer	38 18	90 19		1	9			Chas. Schaefer.
		INDIANA.								
9	20 52	Evansville	37 58	87 33	3	1		None		U. S. Weather Bureau.
		Trevlac	39 16	86 21	2	1				B. N. Doylan.
		IOWA.								
9	20 52	Cedar Rapids	41 56	91 39	2-3		20			J. W. Brush.
		Clinton	41 50	90 13	3	3		None		E. T. Carew.
		Davenport	41 30	90 38		1		do		U. S. Weather Bureau.
		Eldridge	41 38	90 35	3			do		M. H. Calderwood.
		Keokuk	40 22	91 26	3	1	2	do		U. S. Weather Bureau.
		Keosauqua	40 45	91 56	3	1	2	do		J. H. Landes.

TABLE 1.—*Non-instrumental earthquake reports, April, 1917.*

Date.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		KANSAS.								
1917.	*H. m.*		° ′	° ′			*M. s.*			
Apr. 9	20 52	Lawrence	38 58	90 15	2	1				Prof. F. E. Kester.
		KENTUCKY.								
9	20 52	Bardwell	36 53	89 01	3	2				Arthur Halteman.
		Hickman	36 35	89 11	4	2				Mrs. Ella Werner.
		Laketon	36 52	89 00	3	2				E. T. Parker.
		Milburn	36 49	88 53	3	1		None		W. R. Wilkerson.
		Paducah	37 06	88 37	5	1	15	Rumbling		E. Futrell, jr.
		Smithland	37 09	88 29	4	1	12	None		W. D. Threekeld.
		Water Valley	36 35	88 50	3					W. E. Barnes.
		Wickliffe	36 57	90 05	3-4	3	30	None		Prof. G. M. Moore.
		MISSISSIPPI.								
9	20 52	Evansville	34 38	90 19	2					J. M. Phillips.
		MISSOURI.								
9	20 52	Allenton	38 30	90 40	5-6	3			Buildings swayed	W. M. Sevier.
		Augusta	38 34	90 51	5		8	None		W. J. Hays.
		Bismarck	37 48	90 36	5	2	30			G. J. Goeltz.
		Bloomfield	36 54	89 53	4-5	1	10	None		W. E. Cooper.
		Cape Girardeau	37 20	89 31	5	3		do		H. L. Roberts.
		Columbia	38 57	92 20	3-4	1		do		U. S. Weather Bureau.
		Des Arc	37 18	90 37	5	2	30	Rumbling		W. E. McKee.
		De Sota	38 06	90 33	6			do	Bricks fell off chimneys	C. C. Mitakin.
		Doniphan	36 38	90 47	5	2		None		W. W. Martin.
		Dudley	36 48	90 04	5	2	50	do		Mrs. T. J. Fields.
		Farmington	37 47	90 24	5	2	40	Loud		J. B. Smith.
		Fredericktown	37 43	90 16	5-6	3	40			A. T. Lacey.
		Graniteville	37 38	90 44	5	2				Ella Sheahan.
		Greenville	37 07	90 25	5	1	30	Rumbling		
		Hannibal	39 41	91 20	5	1	50	None		U. S. Weather Bureau.
		Hematite	38 13	90 30	5	2		Rumbling		D. O. Jarvis.
		Hendrickson	36 50	90 26	5	1		do		J. L. Harwell.
		High Ridge	38 27	90 32	5-6	1	1 00	do		F. H. Klemme.
		Hogan	37 32	90 39	5	3		do	Many people alarmed	Bessie Wilson.
		Irondale	37 51	90 38	5-6	1	1 30	do		E. S. Tetley.
		Ironton	37 36	90 37	6	2		do	Windows broken	W. H. Delano.
		Jackson	37 25	89 40	5	1	1 00	do		L. M. Bean.
		Kansas City	39 05	94 37	3	1		None		U. S. Weather Bureau.
		Kimmswick	38 23	90 22	5-6	2		Rumbling		J. J. Hilgert.
		Manchester	38 36	90 31	5	1	1 00	do		O. N. Kulhne.
		Marquand	37 27	90 07	5	2		do		Blanche White.
		New Madrid	36 35	89 32	3					Miss Josie Smith.
		Oak Ridge	37 34	89 48	5	1		Rumbling	Dishes rattled	E. C. Trickey.
		Orchard Farm	38 51	90 27	5	2	2 00	do		F. H. Meyer.
		Palmer	37 49	90 54	5	2	11	do	Furniture moved	B. G. Halbert.
		Perryville	37 45	89 51	5	1	15	do		A. E. Deen.
		Pevely	38 17	90 30	5-6	2	4	do		H. J. Englebach.
		Poplar Bluff	36 46	90 21	4-5	1		None		Belle Kinne.
		Potosi	37 57	90 46	5-6	2	30	Rumbling		B. E. Flynn.
		Rolla	37 57	91 45	4	1	30	do	Chandeliers swayed	E. E. Harris.
		St. Charles	38 48	90 30	5	1	15	None	Many alarmed	Louis Saeger.
		St. Louis	38 38	90 12	5-6	2	6	do	Some windows broken	U. S. Weather Bureau.
		St. Marys	37 53	89 59	5	2		Rumbling		J. J. Davis.
		St. Peters	38 48	90 40	5	1	1 00	do		A. B. Iffrig.
		Ste. Genevieve	37 58	90 02	5	1	23	do		L. P. Kern.
		Salem	37 40	91 30	5					C. J. Carnico.
		Seventy Six	37 45	89 38	5	1				G. S. Hatch.
		Sikeston	36 54	89 34	4	1		None		W. E. Burnham.
		Silvermine	37 34	90 27	5	1		Rumbling		Robert Meacher.
		Steelville	37 58	91 20	5	1	5	do	Many people frightened	J. T. Haley.
		Sturdivant	37 03	90 00	4	2		Faint		B. F. Baker.
		Van Buren	36 58	91 01	4	1		None		O. Coleman.
		Warrenton	38 48	91 07	5					Press report.
		Wittenberg	37 45	89 32	5	1	30	Rumbling		C. R. Swan.
		Zion	37 26	90 17	5			do		E. Barker.
9	23 35	Bismarck	37 48	90 36	3	1				G. J. Goeltz.
		Cape Girardeau	37 20	89 31	3	1				H. L. Roberts.
		De Sota	38 06	90 33	3	1				C. C. Mitaken.
		Hematite	38 13	90 30		1	30			D. O. Jarvis.
		Irondale	37 51	90 38		1	30			E. S. Tetley.
		Ironton	37 26	90 37	4	2		Rumbling	Shook oil in lamps	W. H. Delano.
		Jackson	37 25	89 40		1	30			L. M. Bean.
		Perryville	37 45	89 51		1	6			A. E. Deen.
		St. Marys	37 53	89 59	5	1	2 00	Rumbling	Furniture moved	J. J. Davis.
		Ste. Genevieve	37 58	90 02						L. P. Kern.
		Steelville	37 58	91 20						J. T. Haley.
		Zion	37 26	90 17	4	1	1 00	Rumbling		E. Barker.
		MONTANA.								
23	3 50	Butte	46 00	112 31	4	2	10	None		Wm. Hosking.
		NEVADA.								
15	19 02	Fallon	39 30	118 48	3	1	1			E. W. Curtis.
		SOUTH CAROLINA.								
11	19 01	Summerville	33 03	80 14	1-2	1		None		Miss E. H. Gadsden.
		TENNESSEE.								
9	20 52	Hornbeak	36 19	89 21	3-4	1				D. C. Williams.
		Memphis	35 09	90 03	3	2	6	None		U. S. Weather Bureau.
		Tiptonville	36 24	89 30	4-5	1	30			I. F. Lemonds.
		WISCONSIN.								
9	20 52	Madison	43 05	89 23	2	2	6			U. S. Weather Bureau.

TABLE 2.—*Instrumental reports, April, 1917.*

[Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.]

[For significance of symbols see REVIEW for January, 1917, p. 26.]

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.

Lat. 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants:

	V	T_0
E	10	16
N	10	15

(No earthquake recorded during April, 1917.)

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants:

	V	T_0
E	10	13.9
N	10	19.1

(No earthquake recorded during April, 1917.)

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 2	.....	.....	.....	.....	*200	*200	.....	Tremors recorded during 24 hours preceding 15h on dates given.
5	.....	.....	.....	.....	*300	*600	.....	
6	.....	.....	.....	.....	*200	*200	.....	
8	.....	.....	.....	.....	*100	*100	.....	
12	.....	.....	.....	.....	*250	*200	.....	
13	.....	.....	.....	.....	*200	*200	.....	
14	.....	.....	.....	.....	*250	*350	.....	
15	.....	.....	.....	.....	*200	*250	.....	
20	.....	.....	.....	.....	*150	*200	.....	
23	.....	.....	.....	.....	*200	*200	.....	
24	.....	.....	.....	.....	*250	*250	.....	
25	.....	.....	.....	.....	*150	*150	.....	
30	.....	.....	.....	.....	*100	*200	.....	

* Amplitude on instrument.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 03″ W. Elevation, 27.43 meters.

(See record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 6	.....	L_N	4 30 ..	.....	.....	.....	.....	Very small sinusoidal waves of long period.
		F_N	6 10 ..	.....	.....	.....	.....	

Colorado. *Denver*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 8	.....	L_N	12 15 ..	.....	.....	.....	.....	Recurring sinusoidal waves of long period during day. More pronounced during hours marked.
	.....	F_N	14 10 ..	.....	.....	.....	.....	
9	.....	.....	.....	.....	.....	.....	.....	Sinusoidal wavelets recurring during day. Weaker but more frequent than on the 8th.
13	.....	L_N	19 14 ..	.....	.....	.....	.....	Extremely small and irregular waves at intervals during day.
	.....	F_N	19 18 ..	.....	.....	.....	.....	
15	.....	L_N	17 20 ..	.....	.....	.....	.....	Somewhat doubtful as to being seismic.
	.....	F_N	17 23 ..	.....	.....	.....	.....	

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum, undamped. Mechanical registration).

Instrumental constants:

V	T_0
110	6.4

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 9	.....	e	20 57 30	.....	.....	.....	.....	Missouri quake. Minute but distinct tremors with very short period superimposed on microseisms.
		F	20 58 38	.....	.....	.....	.....	
21	.....	e?	1 06 45	.....	.....	.....	.....	
		i	1 13 23	.....	.....	.....	.....	
		F	1 50 ..	.....	.....	.....	.....	
22	.....	e?	6 23 50	.....	.....	.....	.....	Doubtful as to being seismic.
		M	6 32 30	.....	.....	.....	.....	
		M	6 34 22	.....	.....	.....	.....	
		M	6 35 16	.....	.....	.....	.....	
		F	6 45 00	.....	.....	.....	.....	
28	.....	e	16 16 32	.....	.....	.....	.....	Phases indistinguishable.
		M_E	16 20 38	.....	23	.....	.....	
		F	16 45 00	.....	.....	.....	.....	
29	.....	e?	12 02 50	.....	.....	.....	.....	
		e?	12 16 56	.....	.....	.....	.....	
		eL	12 45 00	20	.....	.....	.....	
		F	13 01 00	.....	.....	.....	.....	

District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

Instrumental constants:

	V	T_0	ε
E	165	5.4	0
N	143	5.2	0
Z	*80*	*3.0*	*0*

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1917.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 21	.....	e?	1 05 14	.....	.....	.....	.....	P very uncertain. Heavy microseisms present.
		iS_E	1 13 22	.....	.....	.....	.....	
		iS_N	1 13 23	.....	.....	.....	.....	
		F	1 50 00	.....	.....	.....	.....	
22	.....	e	6 24 41	.....	.....	.....	.....	Phases very difficult to distinguish.
		F	6 52 00	.....	.....	.....	.....	
28	.....	e£	16 16 23	.....	.....	.....	.....	Heavy microseisms present. No distinct maximum.
		e_N	16 16 28	.....	.....	.....	.....	
		S	16 20 19	.....	.....	.....	.....	
		eL_N	16 21 05	.....	.....	.....	.....	
		eL_E	16 21 10	.....	.....	.....	.....	
		F	16 57 00	.....	.....	.....	.....	
29	.....	L_E	12 45 34	.....	.....	.....	.....	Very heavy microseisms present.
		L_N	12 45 51	.....	.....	.....	.....	
		F	12 55 00	.....	.....	.....	.....	

TABLE 2.—*Instrumental reports, April, 1917*—Continued.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neuman.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant.. T_0 18

1917.			H. m. s.	Sec.	μ	μ	km.	
Apr. 3	.....	e	13 25 18	.....	.....	.....	.....	
		L	13 37 36	24	.....	.....	.....	
		M	13 46 36	.....	*500	.....	.....	
		C	13 51 00	.....	.....	.....	.....	
		F	14 04 00	.....	.....	.....	.....	
5	.....	L	4 35 00	.....	.....	.....	.....	Times uncertain; motion of paper not uniform.
		M	4 23 18	.....	*200	.....	.....	
		C	4 45 00	.....	.....	.....	.....	
12	.....	e	3 40 48	.....	.....	.....	.....	
		eL	3 50 06	20	.....	.....	.....	
		M	3 56 00	.....	*400	.....	.....	
		C	3 59 48	.....	.....	.....	.....	
		F	4 08 —	.....	.....	.....	.....	
15	.....	eP	12 29 24	.....	.....	.....	.....	
		L	12 39 06	20	.....	.....	.....	
		M	12 42 18	.....	*100	.....	.....	
		C	12 45 00	.....	.....	.....	.....	
		F	12 49 00	.....	.....	.....	.....	
16	.....	eP	19 30 48	.....	.....	.....	.....	
		eL	19 42 54	.....	.....	.....	.....	
		M	19 49 00	19	*100	.....	.....	
		C	19 53 00	.....	.....	.....	.....	
21	.....	eP	1 23 12	.....	.....	.....	.....	
		eL	1 33 54	20	.....	.....	.....	
		M	1 35 30	.....	*100	.....	.....	
		C	1 43 00	.....	.....	.....	.....	
23	.....	eL	0 46 00	20	.....	.....	.....	
		M	0 46 36	.....	*100	.....	.....	
		F	1 43 00	.....	.....	.....	.....	
28	.....	P	14 13 00	.....	.....	.....	.....	
		eL	14 18 54	21	.....	.....	.....	
		M	14 20 54	.....	*200	.....	.....	
		C	14 23 42	.....	.....	.....	.....	
		F	14 40 —	.....	.....	.....	.....	
29	.....	e	12 27 48	.....	.....	.....	.....	
		M	12 42 00	20	*100	.....	.....	
		F	13 25 00	.....	.....	.....	.....	
29	.....	eP	16 20 54	.....	.....	.....	.....	
		eL	16 32 30	.....	.....	.....	.....	
		M	16 36 24	19	*100	.....	.....	
		F	16 44 —	.....	.....	.....	.....	

* Trace amplitude.

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants..		V	T_0	e
	E	177	3.4	4:1
	N	205	3.4	4:1

1917.			H. m. s.	Sec.	μ	μ	km.	
Apr. 9	.....	P_E	20 53 15	.....	.....	.....	.....	Shock felt locally.
		P_N	20 53 23	.....	.....	.....	.....	
		S_N?	20 53 56	.....	.....	.....	.....	
		S_E?	20 53 57	.....	.....	.....	.....	
		L	20 54 12	.....	.....	.....	.....	
		M_E	20 54 13	.....	.....	.....	.....	Needles left paper at end of maximum.
		M_N	20 54 14	.....	.....	.....	.....	
		F	21 08 —	.....	.....	.....	.....	
9	.....	P	23 35 56	.....	.....	.....	.....	P and S very faint.
		S?	23 36 29	.....	.....	.....	.....	
		L	23 36 45	.....	.....	.....	.....	
		M	23 36 47	.....	3	2	.....	
		F	23 42 —	.....	.....	.....	.....	
28	.....	P_E or S_E.	16 15 19	.....	.....	.....	.....	
		P_N or S_N.	16 15 24	.....	.....	.....	.....	
		L	16 19 32	.....	.....	.....	.....	
		M_N	16 19 44	3-4	.....	.....	.....	
		M_E	16 20 07	.....	.....	.....	.....	
		F	16 40 —	.....	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		V	T_0
	E	10	32
	N	10	27

(No earthquakes recorded during April, 1917.)

Massachusetts. *Cambridge. Harvard University Seismographic Station.* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants..		V	T_0	e
	E	80	23	0
	N	50	25	4:1

(Report for April, 1917, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instruments: Wiechert, 80 kg. astatic, horizontal pendulum.

Instrumental constants..	V	T_0	e
	80	7	5:1

1917.			H. m. s.	Sec.	μ	μ	km.	
Apr. 9	II_D	P_E?	20 52 30	.....	.....	.....	.....	Local shock; period of 4.5 seconds; amplitude 19-20 mm. A very blurred record.
		M	20 52 42	.....	.....	.....	.....	
		F	21 00 00	.....	.....	.....	.....	
9	II_D	P_E?	23 35 06	.....	.....	.....	.....	N–S record too blurred.
		M_E	23 35 18	.....	.....	.....	.....	
		F	23 54 00	.....	.....	.....	.....	
28-29	.....	.....	.....	.....	.....	.....	.....	Hour contact out of order.

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert 80 kg. horizontal.

Instrumental constants..	V	T_0	e:1
	80	7	5:1

(Report for April, 1917, not received.)

New York. *Fordham. Fordham University.* Daniel H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants..		V	T_0	e
	E	72	6.6	1.5:1
	N	72	7.1	3.8:1

(No record, clock connection out of order.)

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants..		V	T_0	e
	E	13	22	4:1
	N	14	25	4:1

(Report for April, 1917, not received.)

TABLE 2.—*Instrumental reports, April, 1917*—Continued.

Panama Canal Zone. *Balboa Heights.* Isthmian Canal Commission.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants.. V 10, T_0 20

(No earthquake recorded during April, 1917.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. L. Adams.

Lat., 18° 08′ 48″ N.; long., 65° 26′ 54″ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants.. E: V 10, T_0 18; N: V 10, T_0 18

(No earthquake recorded during April, 1917.)

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants.. E: V 10, T_0 15; N: V 10, T_0 16

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*km.*	
1917. Apr. 28	.....	e.....	16 18 00	.....	.....	.....	.....	No phases discernible.
		F.....	16 25 00	.....	.....	.....	.....	

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80k. vertical seismograph.

Instrumental constants.. V 120, T_0 26

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*km.*	
1917. Apr. 21	.....	i.....	1 12 50	.....	.....	.....	.....	Masked by microseisms.
		L.....	1 28 ..	17	.....	.....	.....	
			1 37 ..					
		F.....	1 50 ..	.....	.....	.....	.....	
28	.....	e_E.....	16 13 21	1–2	.....	.....	.....	
		i_E.....	16 14 18	1–2	.....	.....	.....	
		i_E.....	16 15 14	1–2	.....	.....	.....	
		S_E?...	16 16 54	3	.....	.....	.....	
		S_N?...	16 16 57	2	.....	.....	.....	
		F.....	16 35 ..	.....	.....	.....	.....	
29	.....	L.....	8 57 ..	10	.....	.....	.....	
29	.....	e_E?....	12 05 16	.....	.....	.....	.....	Distance probably of the order of 11,000 km.
		e_N?...	12 05 30	.....	.....	.....	.....	
		e?.....	12 07 29	.....	.....	.....	.....	
		eS_N?..	12 17 22	.....	.....	.....	.....	
		eS_E?..	12 17 34	.....	.....	.....	.....	
		L.....	12 40 ..	20	.....	.....	.....	L well marked.
			12 44 ..					
		L_N....	12 47 ..	14	.....	.....	.....	
		F.....	13 05 ..	.....	.....	.....	.....	

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. T_0 18. Pillar deviation, 1 mm. swing of boom=0.50″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*km.*	
1917. Apr. 3	.....	L.....	14 14 06	.....	.....	.....	.....	
		M.....	14 17 18	.....	*200	.....	.....	End in air currents.
12	.....	L.....	4 03 30	.....	*50	.....	.....	
		F.....	4 07 00	.....	.....	.....	.....	
21	.....	L?.....	0 46 18	.....	.....	.....	.....	Microseisms going on.
		L.....	1 07 12	.....	.....	.....	.....	
		L.....	1 34 54	.....	*100	.....	.....	
		F.....	1 43 00	.....	.....	.....	.....	
23	.....	e?.....	1 24 18	.....	.....	.....	.....	Minute thickening.
		e.....	1 25 48	.....	*50	.....	.....	
		F.....	1 47 42	.....	.....	.....	.....	
28	.....	L.....	16 17 36	.....	*50	.....	.....	
		F.....	16 19 54	.....	.....	.....	.....	
29	.....	e?.....	12 11 18	.....	.....	.....	.....	
		L.....	12 38 18	.....	.....	.....	.....	
		L.....	12 39 24	.....	.....	.....	.....	
		eL.....	12 41 24	.....	.....	.....	.....	
		M.....	12 42 54	.....	*300	.....	.....	
		F?.....	13 23 00	.....	.....	.....	.....	

*Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instruments: Wiechert, vertical. Milne horizontal pendulum, North; in the meridian.

Instrumental constant.. T_0 18. Pillar deviation: 1 mm. swing of boom=0.54″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude.	Amplitude.	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*m.*	
1917. Apr. 3	.....	P?.....	13 48 30	.....	.....	.....	.....	
		L?.....	13 55 26	.....	.....	.....	.....	
		M.....	14 05 21	.....	*300	.....	.....	
		F.....	14 24 41	.....	.....	.....	.....	
12	.....	M.....	3 58 03	.....	*100	.....	.....	
23	.....	P?.....	1 00 30	.....	.....	.....	.....	
		M.....	1 21 49	.....	*200	.....	.....	
28	.....	e.....	16 16 06	.....	.....	.....	.....	
		e.....	16 16 48	.....	*50	.....	.....	
29	.....	P?.....	12 30 34	.....	.....	.....	.....	
		S?.....	12 32 34	.....	.....	.....	.....	
		L.....	12 34 33	.....	.....	.....	.....	
		M.....	12 38 31	.....	*500	.....	.....	
		F.....	12 49 55	.....	.....	.....	.....	

*Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

Tokyo, Japan, Mar. 18, 1917. (Belated dispatch.)

Heavy earthquake felt in Tokyo to-day from 7:20 to 7:30 a. m., local time.

London, Apr. 4, 1917.

Reuter's Melbourne correspondent reports a local earthquake having been felt in towns in northeastern Victoria. A dispatch to Reuter

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

from Auckland, New Zealand, says a violent eruption of the volcano Waimangu began Sunday and still continues. Two persons have been killed. (Assoc. Press.)

St. Louis, Mo., Apr. 9, 1917.

A distinct earthquake shock was felt for several seconds this afternoon throughout this section. A number of windows were broken and several chimneys were knocked down. The after-vibrations continued for eight minutes. (Assoc. Press.)

[See Table 1 and note hereunder, this issue of the REVIEW.]

Santa Barbara, Cal., Apr. 12, 1917.

A severe earthquake shock was felt here at 8 o'clock to-night. No damage was done. Ventura and Oxnard, 20 and 30 miles east, respectively, along the coast, also felt the shock but experienced no damage. (Assoc. Press.)

Los Angeles, Cal., Apr. 20, 1917.

Two earthquake shocks in rapid succession were felt in various parts of southern California late to-night. No damage was reported. (Assoc. Press.)

London, Apr. 27, 1917, 8:38 a. m.

A violent earthquake in Tuscany and Umbria is reported in a Rome dispatch to the Exchange Telegraph Co. to have occurred on Thursday morning. Many persons are reported killed at Monterchi, near Arezzo, the capital of the Province of that name. Considerable material damage is also reported. (Assoc. Press.)

Rome, Apr. 30, 1917.

Earthquake shocks were reported at Monterchi to-day, the same district laid waste by earth tremors last week. (United Press.)

THE MISSOURI EARTHQUAKE OF APRIL 9, 1917.

By RUY H. FINCH, Assistant.

[Seismological Investigations, Weather Bureau, May 29, 1917.]

On the 9th of April, 1917, a little before 3 p. m., central time, an earthquake occurred near the middle of the eastern border of Missouri that was felt in 10 different States. It was felt over most of Missouri and Illinois, and at many places in Iowa, Wisconsin, Indiana, Kentucky, Tennessee, Mississippi, Arkansas, and Kansas. At first it was thought that the quake had its origin in the New Madrid region, but later reports indicate that the epicenter was somewhere between there and St. Louis.

Most of the information relative to this quake was obtained from some 160 question cards filled out by cooperative observers of the Weather Bureau—postmasters and others—most of whom rendered these reports shortly after the occurrence of the shock while its effects were still fresh in their minds. The majority of the accounts thus received are given in some detail in Table 1, page 182, of this issue of the REVIEW; their intensities and geographical distribution are shown on the accompanying isoseismal map, figure 1.

As was recently pointed out by Montessus de Ballore,[1] the use of isoseismals drawn from estimates of intensities that at best are bound to be at variance is unsatisfactory. Nevertheless such isoseismals give a better idea of the relative distribution of intensities than would be had if omitted.

The area over which this quake was felt, elliptical in shape, extends about 600 miles in a north-south direction and over 500 miles east-west, covering approximately 200,000 square miles. In addition to being both felt and instrumentally recorded at St. Louis University, St. Louis, Mo., and the University of Kansas, Lawrence, Kans., slight records were also obtained at St. Ignatius College, Cleveland, Ohio, about 520 miles away, and the Weather Bureau, Washington, D. C., about 760 miles from the epicentral region.

The beginning of the disturbance as given by the majority of observers was $2^h\ 52^m$ to $2^h\ 53^m$ p. m. (Central time). The time at origin as calculated from the seismograph record of the University of Kansas was $2^h\ 52^m\ 24^s \pm 5^s$. This is in fair agreement with the record obtained at St. Louis University, within a very short distance of the origin, which began at $2^h\ 52^m\ 30^s$ p. m.

Sounds were quite generally reported within the territory bounded by the V isoseismal. Within the VI isoseismal many places reported that heavy rumbling both preceded and accompanied the shock.

No good evidence as to the direction of the vibrations is at hand, though the majority of the observers thought it was east-west. The observer at Ironton, Mo., Mr. W. H. Delano, says that he looked down and could see the earth rock—rise up and sway back and forth as from west to east.

The damage occasioned by this quake was slight. Some windows were broken, bricks shaken from chimneys, and plaster cracked over most of the territory bounded by the VI isoseismal. Several horses were thrown to the pavement in different parts of St. Louis. A painter working on a ladder in Granite City, Mo., was shaken off and fell into a flower garden but was unharmed. Many people hurriedly left their homes in fright. The school children at Warrenton, Mo., and several other places, were thrown into a panic and were dismissed. As is well known, birds and many other animals are more sensitive to light shocks than human beings. This may explain why a team of horses in Golconda, Ill., were uneasy and restless at the time of the quake while the driver felt nothing.

No preliminary shocks to the main quake were noticed except for a slight tremor that was recorded on April 9 by the seismograph at St. Louis University, $8^h\ 45^m$ a. m. A second shock at $5^h\ 35^m$ p. m. was felt quite generally over most of the southern half of the territory bounded by the V isoseismal and was specially noticeable in the corresponding part within the VI isoseismal. This would lead one to think that the origin was located somewhere in the southern half of the VI isoseismal area.

The middle Mississippi Valley, the southern Appalachian region, the Atlantic Coastal Plain in the vicinity of Charleston, S. C., northern and eastern New York, and New England are the well-known seismic regions of the eastern United States. Most, though by no means all, of the middle Mississippi Valley quakes occur in the New Madrid region. Two quakes, one occurring on May 26, 1909, the other on January 2, 1912, and described by Udden [2] apparently had their origin southwest of Chicago. Scarcely a year passes without one or more quakes being felt in the New Madrid region. One on October 7, 1857, whose origin appears to have been either a little to the south of St. Louis or near New Madrid, was not quite as severe as the one under discussion. Another that occurred on October 31, 1895, was probably the most severe since the great shocks of 1811–12. The last shock of note in this region occurred on December 7, 1915, when an intensity of V Rossi-Forel was reported. Several observers ventured the assertion that the quake under discussion was the most severe since the great New Madrid earthquake, and this may be true for the region about St. Louis but is improbable as regards southeastern Missouri.

Judging from the distance to which the waves of this disturbance was propagated it seems probable that the origin was at some depth below the surface. It is known that a series of faults, running in a general east-west direction, occur in the underlying Paleozoic rock of the central region of this earthquake, and it is probable that the recent shake had its origin in one or more of these faults.

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[1] Bull., Seis. soc. America.

[2] Trans., Illinois Academy of science, 1912, 5:—

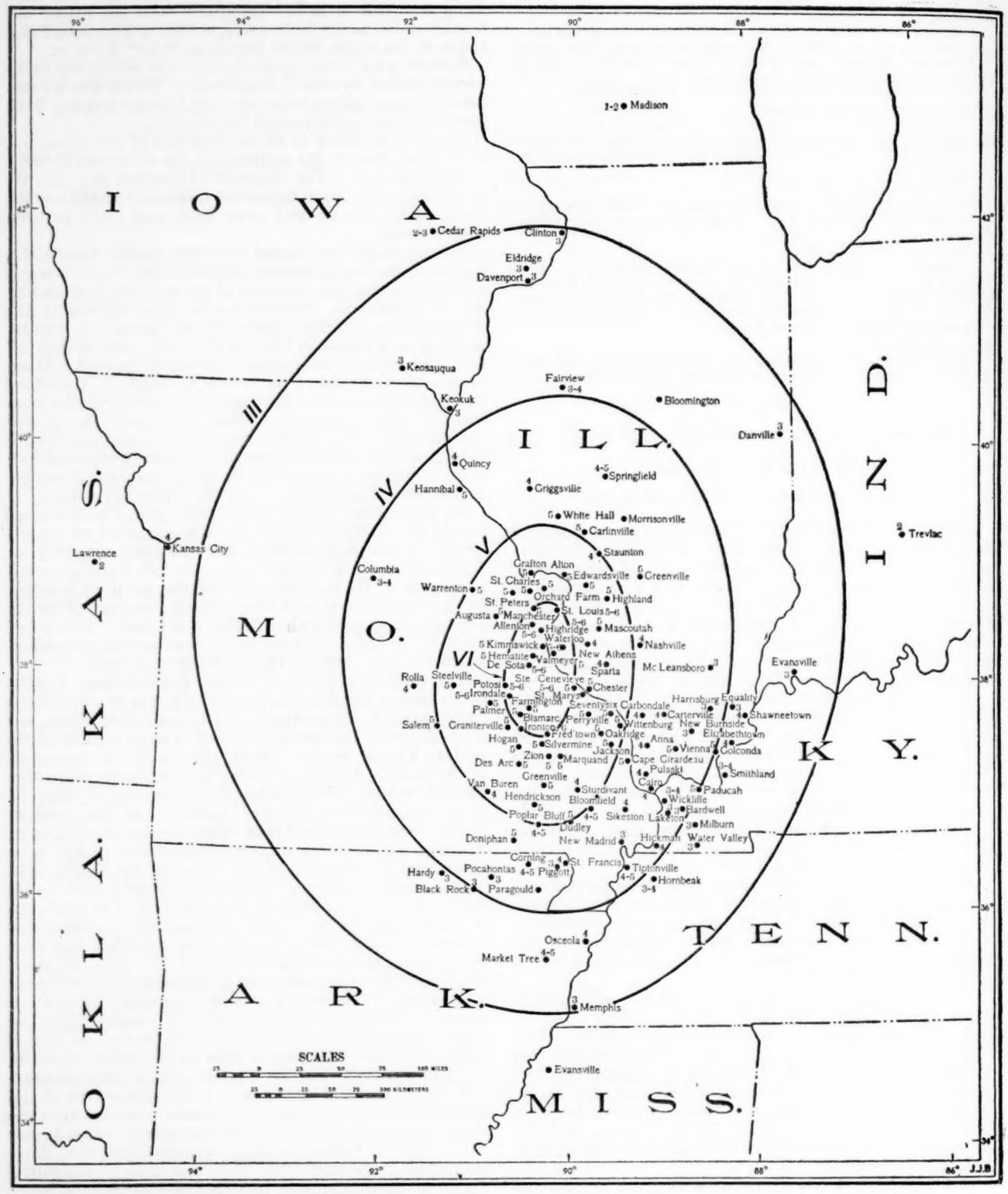


Fig. 1.—Isoseismals of the earthquake of April 9, 1917, in Missouri and Illinois. Arabic numbers opposite places indicate Rossi-Forel intensities.

SECTION VI.—BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Barber, Frederic Delos, *and others.*
First course in general science, by F. D. Barber, M. L. Fuller, J. L. Pricer, and H. W. Adams. New York. 1916. vii, 607 p. front. illus. figures. 19½cm. [Chapter 4. The weather, by M. L. Fuller.]

Blomgren, Axel S.
Kortfattad nautisk meteorologi samt utprickningssystem och stormvarningssignaler. Göteborg. [1915] 76 p. (incl. title-page) 7 plates (partly col.) figures. tables (partly fold.) 20½cm. [Plates give nautical storm signals for twelve countries.]

Eredia, Filippo, *comp.*
Norme per l'impianto e per il funzionamento delle stazioni termo-udometriche coloniali. Roma. 1915. 44 p. (incl. title-page) figures. tables. 23½cm. At head of title: Ministero delle colonie. (Estratto dal Bollettino d'informazioni, anno 3, N. 5-7.)

Huntington, Ellsworth.
Temperature optima for human energy. 25½cm. (Excerpted from Proceedings of the National academy of sciences, v. 3, Feb. 1917, p. 127–133.)

King, Louis Vessot.
On the acoustic efficiency of fog-signal machinery. [New York] 1917. 6 figures. 3 charts. 24cm. (Reprinted from the Journal of the Franklin institute, March, 1917, p. 259–286.)

Kodaikanál and Madras observatories.
Annual report of the director for 1916. Madras. 1917. [2 l] 24 p. tables. 33½cm.

Lick Observatory.
Refraction at Mount Hamilton, by R. H. Tucker. [Sacramento] 1917. University of California publications. Astronomy, v. 9, p. 56–63. 30½cm. Lick observatory bulletin no. 292.

McClatchie, Alfred J.
Relation of weather to crops and varieties adapted to Arizona conditions, by A. J. McClatchie and J. E. Coit and the Station staff. Tucson. 1916. (University of Arizona. Agricultural experiment station. Bulletin no. 78, p. [45]–118.) 23cm. "Revision of Bulletin no. 61."

Montevideo. Observatorio central del Prado.
Resumen y discusión de las observaciones meteorológicas del observatorio central. Período 1901–1915, por Luis Morandi. Montevideo. 1917. 19 p. (incl. title-page) tables. 30cm. At head of title: Instituto nacional físico-climatológico. [Includes absolute extremes of temperature at 10 places and precipitation normals at 52 places in Uruguay.]

Oña. Colegio maximo de la Compañia de Jesus.
Observaciones meteorológicas [1916] Oña. 1917. unpaged. tables. 24cm.

Paris. Bureau of longitudes.
Wireless time signals: radio-telegraphic time and weather signals transmitted from the Eiffel tower, and their reception. Authorized tr. with additional tables and data. London, New York. 1915. ix, 133 p. illus. fold. plate. 19cm.

Robbins, Wilfred W.
Native vegetation and climate of Colorado in their relation to agriculture. Fort Collins, Colo. 1917. 56 p. (incl. title-page) charts (partly fold.) illus. figures. tables. 23cm. At head of title: Agricultural experiment station of the Colorado agricultural college. Bulletin 224. Feb. 1917. [With several climatic charts, detailed frost data, etc.]

Shaw, William Napier.
Principia atmospherica; a study of the circulation of the atmosphere. Edinburgh, London. 1914. figures. tables. 25½cm. (Reprint from the Proceedings of the Royal society of Edinburgh. Session 1913–1914, v. 34, pt. 1, no. 9, p. 77–112.) [Reprinted in this REVIEW, 1914.]

Toronto observatory.
Results of meteorological, magnetical, and seismological observations, 1916. Compiled by Jas. Young . . . Toronto. 1917. 37 [10] p. (incl. title-page) tables. 19cm. At head of title: Dept. of marine and fisheries. Dominion of Canada.

Udden, Anton D.
Cyclonic distribution of weather elements for Davenport, Iowa. 12 p. 19 figures. 23½cm. (Reprint from Transactions of the Illinois academy of science, v. 7.)

U. S. Dept. of the interior. Office of the secretary.
General information regarding the territory of Alaska. Edition of March, 1917. Washington. 1917. 72 p. maps (partly fold.) tables. 23½cm. [Climate, p. 9–12.]

U. S. Naval observatory. Nautical almanac office.
Total eclipse of the sun June 8, 1918. Washington. 1917. 32 p. (incl. title-page) 4 fold. charts. tables. 23½cm. At head of title: Supplement to the American ephemeris, 1918. (Part 1. Meterological data furnished by the U. S. Weather bureau. Part 2. Astronomical data and charts.) Charts 3–4 in envelope at back.

Venice. Ufficio idrografico.
Norme ed istruzioni per il Servizio meteorologico. (Edizione provvisoria) Parte 2a. Tabelle. Venezia. 1916. 87p. tables. 26cm. At head of title: R. magistrato alle acque.

Walker, James.
Introduction to physical chemistry; 7th ed. London. 1913. xii, 412 p. figures. tables. 22½cm.

West, F. L., & Edlefsen, N. E.
Freezing of fruit buds. Lehi, Utah. Lehi Sun print. 1917. 24 p. (incl. title-page) 9 tables. 6 figures. 23cm. At head of title: Utah agricultural college. Experiment station. Bulletin no. 151. [Bibliography, p. 22–24.]

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Electrical world. New York. v. 69. March 31, 1917.
Piper, C. W. Analysis of damage caused by lightning. p. 609. [Statistics of damage to electrical equipment and suggestions as to protection.]

Meteorological society of Japan. Journal. Tokyo. 36th year. April 1917.
Okada, T. Geometrical derivation of the equations of motion for a material particle moving under gravity on the rotating earth. p. 25–33.
Onisi, N. Seasonal correlation at Hankow in the Yangtze valley and Kôhfu in central Japan. p. 34–35. [Abstract.]
Akamatu, T. Correlation between the barometric pressure gradient at Nafa in the Riukiu Islands for January to April and the rainfall air temperature and sunshine duration at Kôti on the south coast of Japan for July. p. 35–39. [Abstract.]

Nature. London. v. 99. 1917.
Harding, Cha[rle]s. The recent cold weather. p. 153. (Apr. 19.)
Dobson, Gordon, *and* **Stromeyer, C. E.** Aeroplanes and atmospheric gustiness. p. 164–165. [Apr. 26.]

Scientific American. New York. v. 116. May 12, 1917.
Zeppelin barometers. p. 472. [Describes a form of silver-foil hygroscope.]

Scientific American supplement. New York. v. 83. May 19, 1917.

Ulke, Titus. Life on glaciers and snow fields. Animals and plants that flourish amid snow and ice. p. 316–317.

Seismological society of America. Bulletin. Stanford university. v. 6.

Montessus de Ballore, [Fernand] de. Earthquake intensity scales. p. 227–231. (Dec., 1916.)

Palmer, Andrew H. California earthquakes during 1916. p. 1–17. (Mar., 1917.)

Lemos, Alix. A new liquid damping contrivance for seismographs. p. 18–26. (Mar., 1917.)

Reid, Harry Fielding. Note on the earthquakes at Almirante, Republic of Panama, in April, 1916. p. 27–30. (Mar., 1917.)

Montessus de Ballore [Fernand] de. The Mexican earthquake of November 12, 1912. p. 31–33. (Mar., 1917.)

Klotz, Otto. The earthquake of January 30, 1917. p. 34–36. (Mar., 1917.)

Symons's meteorological magazine. London. v. 52. March, 1917.

Bonacina, L. C. W. The frost of January and February, 1917. p. 13–15.

Simpson, G. C. Water drops below freezing point. p. 17–18.

Tycos Rochester. New York. v. 7. April, 1917.

The wonderworld of ice crystals. p. 9–13. [Repr. from Pop. Sci. Mo.]

Astronomie. Paris. 31 année. Avril 1917.

Flammarion, Camille. Fleurs d'hiver et fleurs de printemps. p. 145–146. [Brief essay on snow and ice crystals, with photographic illustrations.]

Académie des sciences. Comptes rendus. Paris. Tome 164. 1917.

Deslandres, H[enri.] Influence des canonnades intenses et prolongées sur la chute de la pluie. p. 613–615. (Avril 23.) [Author thinks the ionization of the air by prolonged cannonading may promote rainfall.]

Sebert, Les violentes canonnades peuvent-elles provoquer la pluie? p. 663–669. (30 avril.)

Nature. Paris. 45 année. 21 avril 1917.

Rabot, Charles. L'hiver 1917 dans la Scandinave. p. 248–249.

Reale accademia dei Lincei. Atti. Roma. v. 26. 1 sem. no. 4. Febbraio 1917.

Eredia, Filippo. Andamento annuale della pressione barometrica in Italia. p. 240–245.

SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF APRIL, 1917.

P. C. DAY, Climatologist and Chief of Division.

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds are graphically shown on Chart VII, while the average values for April, 1917, at the several stations, with the departures from the normal, are shown in Tables I and III.

At the beginning of the month relatively low pressure prevailed from New England and the lower Lakes Region southwestward to the west Gulf States; elsewhere it was generally above the normal, being decidedly high in the southeast, in the Great Plains States and to the westward. During the first half of the month a number of rather extensive low-pressure areas moved from the southwest, eastward or northeastward across the country. While they were followed by relatively high-pressure areas yet in most central and southern districts the pressure during this period was generally below the average, except for a few days early in the month and again about the end of the first decade when rather extensive HIGHS moved over those sections. In the northern portion of the country, as well as west of the Rocky Mountains, with the exception of the passage of an occasional LOW, the pressure was generally above the average during the above period.

During the latter half of the month a number of rather extensive low and high pressure areas moved rather slowly across the country, but the pressure average was below normal in the South, while in most central and northern districts it was above the average much of the time.

The month closed with the pressure below the normal in practically all sections, except the extreme northeastern Canadian Provinces, the Rocky Mountains region, and along the South Pacific coast, where it was normal or slightly above.

For April as a whole, the barometric pressure averaged below the normal east of the Mississippi River, except in the upper Lakes Region; it was also relatively low in Missouri, Arkansas, most of Texas, and west of the Rocky Mountains generally, except in central and southern California. Elsewhere it was above the average. The departures from the normal were generally small except in the northwestern Canadian Provinces where rather pronounced positive departures occurred.

The distribution of the HIGHS and LOWS was generally favorable for northerly winds in the northern half of the country east of the Rocky Mountains, while southward the winds were most frequently from southerly points. West of the Rocky Mountains variable winds prevailed.

TEMPERATURE.

The temperature for the first decade of April was much lower than the normal in nearly all the eastern part of the country and frosts occurred as far south as central Mississippi and central South Carolina; but it was slightly warmer than the average in the upper Missouri Valley, over most of California, Nevada, and Arizona, and in the central portions of Oregon and Washington. Freezing temperature extended as far south as the northern portion of North Carolina, Tennessee, and northern Texas, while in northern Maine and parts of the central Rocky Mountain district temperatures fell as low as 10° F. From April 11 to 16 unusually cool weather prevailed in nearly all sections, with widespread frost as far south as the northern portions of the east Gulf States. However, on the 17th the weather became warmer in the central valleys and to the southwest, and during the next few days warmer weather obtained in most eastern districts, the temperature over the interior districts being much above normal. In Arizona and portions of adjacent States it continued unseasonably cold.

About the 20th cooler weather with frosts appeared in Kansas, Oklahoma, and Texas, and by the 23d low temperatures for April prevailed in the Lakes Region and upper Mississippi Valley; but in most of the central and southern districts east of the Rocky Mountains it was warmer than usual for the season. West of the Rocky Mountains cool weather continued except in portions of California and Oregon. During the latter part of the month the temperature averaged below the normal over practically the whole country, except in the cotton belt, the southern and central Appalachian region, central and northern California, and southwestern Oregon.

April closed with low temperatures—for the season—in practically all the principal grain-growing areas, and in the western and north-central portions of the cotton belt.

For the month as a whole the temperature was below the normal throughout the country, except south of Pennsylvania and the Ohio River and locally in Texas and California where the month was somewhat warmer than usual. The minus departures averaged from 3 to 6 degrees a day over the upper Mississippi Valley, the northern and central portions of the Great Plains, and the Rocky Mountains and Plateau States.

PRECIPITATION.

Plentiful precipitation occurred during the first 10 days of April in northern California, western Oregon, and most of Washington; but generally there was no rain in the vicinity of the Mexican boundary and the southern Plains Region. Heavy rain fell in Missouri and the Ohio Valley States and southward to the Gulf, and also in central and northern Georgia, and portions of the Carolinas. Moderate rainfall occurred in Iowa, southern Georgia, western Florida, and in the eastern portions of Texas, Oklahoma, Kansas, and Nebraska, as well as in the Middle Atlantic and New England States.

During the second decade there was little rain in the eastern part of the country north of the Ohio River and Maryland, but moderate falls occurred in portions of the Carolinas and Georgia, and generous amounts were received in the southern part of Florida. Most of Louisiana and Missouri had considerable rain, while in the Plains States there were moderate amounts over large areas. In Texas showers failed to reach many of the southern and western counties, but much of that State

received considerable moisture, as did nearly all of Oklahoma and Kansas, where the drought was well broken. From the Rocky Mountains westward the distribution of precipitation was irregular. In portions of Nevada and Arizona, southern California, and Colorado, there were good rains, and in nearly all of Idaho and Oregon with portions of the States adjoining, precipitation was heavy.

The rainfall during the third decade was heavy in the lower Missouri and middle Mississippi Valleys, and in north-central Texas. In general there was moderate rainfall in the Ohio Valley and Lakes Region, most of the Plains States, in the central Rocky Mountains district and portions of the far Northwest, but practically no rain fell in southern and western Texas and to the westward.

For April as a whole the precipitation was heavy along the northern Pacific coast, in the north-central portions of Arizona, and generally in the Ohio, central, and lower Mississippi, and lower Missouri valleys, and in the eastern portions of the Plains States. Elsewhere the amounts were moderate to small, with little or no rainfall in extreme western Texas and the southern portions of New Mexico and Arizona.

RELATIVE HUMIDITY.

The relative humidity for April as a whole was generally above the normal in the northern and western portions of the country except in California, where it was mostly below the average. The relative humidity was less than usual for April in the southern half of the country from the Great Plains eastward, except in relatively small areas over the South Atlantic and Central Gulf States.

GENERAL SUMMARY.

Farm work was delayed by the cold and wet weather in most northern districts, and in the Southwest and Southeast the dry weather retarded plowing and seeding, but favorable progress was made during the middle and latter parts of the month in the more central districts. However, vegetation was generally backward.

As a whole, the weather was favorable for winter wheat in the principal wheat-growing districts, except in portions of Ohlahoma and Texas, where the moisture was insufficient. The seeding of spring wheat made good progress, but was somewhat delayed in Montana and North Dakota, due to unfavorable weather conditions; and the seeding of rye, oats, and barley progressed favorably in most districts. The planting of cotton and corn, while somewhat delayed, made good progress under the more favorable weather conditions during the latter half of the month. Potatoes and truck crops, although somewhat retarded in the north by the cold weather, made good progress in most sections. All reports indicate a decided increase in most truck crops and potatoes. Pastures and ranges were late and short in most sections and dry feed was scarce, resulting in live stock being in unusually poor condition, with considerable loss in some districts. The weather was generally favorable for most fruits, which, at the close of the month, were in excellent condition. Peaches were extensively winter-killed.

SEVERE LOCAL STORMS.

The following notes of severe storms have been extracted from reports by officials of the Weather Bureau:

Florida.—On the afternoon of April 5, 1917, a severe storm, with decided tornadic characteristics, occurred at Seffner and other points adjacent to Tampa. A child was killed and a number of houses were blown down and trees uprooted. Estimated velocity of wind at Seddon Island, 90 miles an hour. (See above, p. 167.)

A severe thunderstorm, with heavy rain and hail, occurred at Miami on the 13th. The storm had some characteristics of the tornado. In its path a school building was demolished and a number of houses unroofed. About 300 grapefruit trees were uprooted, some of which had survived several hurricanes. The damage to property amounted to $6,000 or $8,000.

Tennessee.—A severe local storm swept over Binghamton, a suburb of Memphis, about noon on April 1, 1917, damaging considerable property. Trees and telephone poles were blown down, a number of houses were unroofed, and two churches were badly wrecked, in one of which three persons were injured. The property loss was estimated at $200,000. A small boat crossing the Mississippi River was capsized by the wind, resulting in the drowning of two persons. A heavy rain and windstorm at Union City on the same day damaged a number of buildings and flooded hundreds of acres of land. During the afternoon of the 29th a wind and electric storm at Jefferson City destroyed some timber and fruit trees and killed one man. The town of Dresden suffered to the extent of several thousands dollars in minor losses from a rapidly moving storm of but a few minutes' duration about 4 p. m. of the 30th. It came from the northwest and cut a path about 100 yards wide and 1½ miles long. Only one person was reported injured.

Texas.—About 4 p. m. on April 11, 1917, a severe storm moved over Austin, accompanied by very heavy hail, some of the stones weighing between 2 and 3 ounces. The hail continued less than 5 minutes, but its depth on the ground was about 3 inches. Truck gardens, fruit, windows, greenhouses, automobile tops, and some shingle and tin roofs were badly damaged. The estimated loss was $50,000.

Average accumulated departures for April, 1917.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	0–10		P.ct.	
New England	41.8	−1.7	− 4.7	2.67	−0.40	−1.60	6.3	+0.7	75	+ 1
Middle Atlantic	51.3	+0.6	+ 1.4	2.12	−1.00	−1.70	5.3	0.0	66	− 2
South Atlantic	64.1	+3.0	+ 9.0	2.83	−0.60	−3.40	3.5	−0.7	68	− 3
Florida Peninsula	73.2	−0.6	+ 4.8	2.15	+0.30	−3.60	3.4	−0.3	71	− 3
East Gulf	65.3	+0.7	+ 9.1	3.70	−0.40	+1.10	4.0	−1.0	68	− 4
West Gulf	64.5	−1.1	+ 6.5	2.92	−0.60	−4.90	4.6	−0.5	68	− 5
Ohio Valley and Tennessee	54.2	−0.4	+ 0.3	3.76	+0.20	+2.20	5.7	+0.3	65	− 1
Lower Lakes	43.3	−1.9	− 5.9	3.06	+0.70	−0.30	6.7	+0.9	73	+ 2
Upper Lakes	38.2	−2.6	−11.7	2.74	+0.40	−1.00	6.2	+0.5	76	+ 3
North Dakota	37.6	−3.0	−10.1	1.61	−0.20	−0.60	6.4	+1.2	72	+ 5
Upper Mississippi Valley	47.8	−2.7	− 7.1	3.90	+0.90	−0.20	6.5	+1.2	70	+ 2
Missouri Valley	47.9	−2.6	− 0.4	3.96	+1.10	+0.30	6.3	+1.0	70	+ 6
Northern slope	38.9	−3.9	−13.3	1.98	+0.40	+0.30	6.5	+1.4	67	+ 7
Middle slope	50.8	−2.9	+ 0.6	1.80	−0.40	−1.00	5.5	+0.8	60	+ 2
Southern slope	61.7	−0.7	+ 4.8	1.33	−0.60	−2.10	2.5	−1.9	42	−11
Southern Plateau	55.3	−2.5	−11.1	0.36	0.00	−0.60	2.6	−0.2	39	+ 5
Middle Plateau	44.8	−3.8	−27.0	1.07	−0.10	−1.20	5.1	+1.0	50	+ 2
Northern Plateau	44.9	−4.2	−17.1	2.46	+1.10	−0.20	7.4	+2.1	63	+ 7
North Pacific	47.0	−2.6	− 9.3	5.97	+0.50	−3.60	7.7	+1.5	82	+ 6
Middle Pacific	53.3	−0.3	− 7.3	1.20	−0.90	−5.10	3.7	−0.5	67	− 3
South Pacific	57.4	−0.5	− 3.9	0.46	−0.60	−1.90	3.3	−0.5	67	− 2

WEATHER CONDITIONS OVER THE NORTH ATLANTIC OCEAN DURING APRIL, 1916.

The data furnished are for April, 1916; comparison and study of the same should be in connection with those appearing in the REVIEW for that month. Chart IX (XLV–41) shows for April, 1916, the averages of pressure, temperature, and prevailing direction of the wind at 7 a. m., 75th meridian time (Greenwich mean noon), together with notes on the locations and courses of the more severe storms of the month.

PRESSURE.

The distribution of the average monthly pressure for April, 1916, as shown on Chart IX, was, in most respects, similar to the normal. The North Atlantic, or Azores HIGH, was slightly north of its usual position, and nearly normal in intensity, while a second HIGH, with a crest of 30.05 inches and of limited area, was central near Birmingham, Ala. The southern portion of the Icelandic LOW was plainly shown by an isobar of 29.70 inches that extended from the south coast of Iceland toward the south and east. There was also a shallow area of low pressure central near latitude 45° N., longitude 55° W., where the average barometer reading was 29.81 inches. The lowest average monthly pressure reading for any one 5° square was 29.67 inches, and occurred in the square between latitudes 60°–65° N., longitudes 5°–10° W., where the lowest individual reading was 29 inches, on the 12th, and the highest 30.28 inches, on the 26th. The highest average pressure was 30.23 inches, in each of the two squares between latitudes 40°–45°, longitudes 20°–30°, where the lowest reading was 29.79 inches, on the 30th, and the highest 30.62 inches, on the 11th. While the pressure changes from day to day were marked in the higher latitudes, they were not greater than should be expected for the spring.

The averages for the three decades of April, 1916, varied considerably in many instances, and while in some localities the average pressure for the first decade was higher than that during the last two, in other regions the conditions were reversed. In the square between latitudes 60°–65°, longitudes 10°–15° W., the averages were as follows: First decade, 29.72 inches; second, 29.51 inches; third, 29.83 inches. In the square between latitudes 50°–55°, longitudes 10°–15° W., the figures were: First decade, 30.16 inches; second, 29.79 inches; third, 29.89 inches. In mid-ocean the decrease of pressure throughout the month was decided, and comparatively uniform, as shown by the averages for the square between latitudes 40°–45°, longitudes 35°–40°, which were as follows: First decade, 30.37 inches; second, 30.09 inches; third, 29.79 inches. The variation was not large in the waters adjacent to the American coast, and the figures for the square between latitudes 40°–45°, longitudes 65°–70°, were: First decade, 29.92 inches; second, 29.86 inches; third, 29.88 inches. Along the southern Gulf Coast the variation was also small, although the pressure for the middle decade was slightly higher than for the first and third, which were nearly the same.

GALES.

April usually shows a marked decrease in the number of gales as compared with March, and the month under discussion was no exception to the general rule. Over nearly the entire ocean the number of gales for April, 1916, was considerably below the normal, and in the vicinity of the steamer lanes they were not observed on more than four days in any one 5-degree square. The only exceptions occurred in the two squares immediately north of the Bermudas, where gales were reported on 6 days, a percentage of 20, while the normal for that locality is 13%. Between the 35th and 45th parallels all the winds of gale force occurred in the first 20 days of the month, none being reported later than the 19th. From April 1 to 7, a number of shallow depressions existed over the western division of the ocean, and from the 2d to the 13th a LOW of more decided character almost continuously occupied the region between Iceland and the Scandinavian Peninsula, although it was so far north that only the southern portion could be shown on the chart during the greater part of that period. On the 7th, a LOW (I on Chart IX) of slight intensity and attended by light to moderate winds, was central near Mobile, Ala., where the barometer read 29.70 inches. On the 8th the center of this LOW was near Hatteras, and the general conditions of the wind and weather had changed but little since the previous day. It moved in a northeasterly direction, increasing somewhat in intensity, and on the 9th, was near Nantucket, the barometer at that place reading 29.36 inches. A few vessels between the American coast and the 60th meridian reported southwesterly gales of from 40 to 55 miles an hour, while snow and fog were observed at different points along the coast, between New York and the Capes.

Continuing on its northeasterly course, the center of depression I was near Cape Ray, N. F., on the 10th, where the barometer had fallen to 29.20 inches. Moderate winds prevailed between the center and the 38th parallel, although in the territory between that line and the 34th parallel, and the 55th and 70th meridians, moderate to strong gales were encountered. On the same day the Icelandic LOW was unusually pronounced, the barometer reading at Reykavik being 29.03 inches. At the same time the Azores HIGH, with a crest of 30.70 inches, was central near latitude 40, longitude 30. The steep gradient between this high and the two lows caused heavy winds between the 50th and 55th parallels, and the 20th and 25th meridians, where several vessels encountered northwesterly gales of from 40 to 55 miles an hour, while the barometer read from 30 inches to 30.22 inches.

On Chart III (XLIV–48)—Tracks of Low Areas, in the April, 1916, MONTHLY WEATHER REVIEW, a LOW (II on our Chart IX) is shown that first appeared on the map in sourthen Alberta on the evening of the 10th. This disturbance moved across the country at a comparatively rapid rate, and, on the 14th, was central near New York. The depression was shallow in character, and only light to moderate winds were recorded in its vicinity. A smaller LOW of much greater intensity was central, on this date, about 3 degrees east of St. Johns, N. F., and observations showed moderate to strong gales over a large territory between the 38th and 47th parallels and the 37th and 57th meridians.

Of these LOWS the first (II on Chart IX) moved rapidly due eastward and on the 15th was central near latitude 40°N., longitude 62°W. It had increased considerably in intensity, as four vessels near the center recorded barometer readings of from 28.82 to 28.90 inches, while strong northwesterly gales raged over a large area extending as far south as the Bermudas. The disturbance continued its eastwardly movement at a diminished rate of translation, and on the 16th its center was near latitude 40°N., longitude 55°W., with a minimum barometer reading of 28.75 inches. It was then accompanied by

northerly gales between the center and the American coast. The disturbance then curved slightly toward the northeast, and on the 17th was near latitude 42°, longitude 50°; the barometer had risen to 29.25 inches and the storm area had decreased since the previous day, although a number of vessels between the 40th and 60th meridians encountered strong gales. This LOW moved but little between the 18th and the 22d, and conditions of wind and weather remained practically unchanged until the 20th, when the area began to fill in and the winds to decrease in force.

On the 22d fog was reported off the Banks of Newfoundland. On the 23d and 24th a well-developed LOW existed in the territory between the 35th and 43d parallels, and the 65th and 75th meridians, light to moderate winds prevailing over a considerable area, while fog was also reported by a number of vessels near the center. This disturbance moved rapidly toward the east, and on the 25th was central near latitude 42°, longitude 57°, the weather conditions remaining about the same as on the previous day. On the 25th another LOW had its center near latitude 48°, longitude 19°, while gales were reported from vessels within its limited area. From the 26th to the 28th there were no well-defined cyclonic disturbances on the chart, although a number of shallow depressions existed, accompanied by light to moderate winds, while fog prevailed in different localities in mid-ocean. On the 30th a LOW of limited extent was central about 5 degrees east of Hatteras, and easterly and northeasterly gales of from 40 to 60 miles an hour were reported by a number of vessels between the 70th meridian and the American coast.

TEMPERATURE.

The mean monthly temperature of the air over the ocean was, as a whole, slightly above the normal, the positive departures ranging from 1 to 5 degrees in mid-ocean and in the waters adjacent to the European coast. Along the American coast it was near the normal, while in West Indian waters and the Gulf of Mexico the departures ranged from 0 to −4 degrees. The departures at a number of Canadian and U. S. Weather Bureau stations on the Atlantic and Gulf coasts were as follows:

	°F		°F.
St. Johns, N. F.	+2.5	Nantucket, Mass.	−1.4
Sydney, C. B. I.	+1.2	Block Island, R. I.	−1.4
Halifax, N. S.	+2.8	New York, N. Y.	−1.0
Norfolk, Va.	+0.4	Key West, Fla	−1.6
Hatteras, N. C.	−0.3	Tampa, Fla.	−1.6
Charleston, S. C.	+0.2	New Orleans, La.	−0.1
Eastport, Me.	+1.5	Galveston, Tex.	−1.7
Portland, Me.	−1.5	Corpus Christi, Tex.	−1.3
Boston, Mass.	+0.3		

The lowest temperature reported by any one vessel during the month was 33° and occurred on the 8th in the 5-degree square that includes the east coast of Labrador, while the highest temperature for the same square was 39° on a number of days. The usual seasonal rise in temperature during the month was not apparent in the higher latitudes, although appreciable in some localities south of the 40th parallel.

FOG.

Off the Banks of Newfoundland and in the waters adjacent to the American coast, the amount of fog was somewhat less than usual, while over the steamer lanes east of the 55th meridian it was near the normal.

SNOW AND HAIL.

There was a marked decrease in the number of days on which snow and hail were observed, as compared with March. Snow was reported on the 2d, 6th, and 19th on the eastern portion of the steamer routes, and on the 9th off the New England coast, while hail was observed on the 19th near latitude 52°, longitude 17° W.

Winds of 50 miles per hour (22.4 m./sec.), or over, April, 1917.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
		Mis./hr.				*Mis./hr.*	
Block Island, R. I.	9	54	n.	New York, N. Y.	9	56	nw.
Buffalo, N. Y.	1	50	sw.	Do.	10	67	nw.
Canton, N. Y.	2	59	sw.	Norfolk, Va.	6	51	w.
Charlotte, N. C.	5	51	sw.	Do.	21	64	w.
Do.	30	60	sw.	Oklahoma, Okla.	3	50	s.
Dodge City, Kans.	17	60	se.	Pensacola, Fla.	5	63	sw.
Do.	18	52	s.	Do.	8	50	w.
El Paso, Tex.	18	51	nw.	Pittsburgh, Pa.	18	54	nw.
Do.	29	52	sw.	Do.	25	51	se.
Erie, Pa.	5	62	se.	Point Reyes			
Do.	25	55	se.	Light, Cal.	3	51	nw.
Evansville, Ind.	30	58	sw.	Do.	14	53	nw.
Fort Smith, Ark.	19	52	sw.	Do.	25	54	nw.
Do.	30	56	w.	Do.	26	61	nw.
Hatteras, N. C.	8	50	s.	Portland, Me.	4	63	nw.
Indianapolis, Ind.	5	52	nw.	Do.	10	56	nw.
Jacksonville, Fla.	8	50	sw.	Do.	11	53	nw.
Lexington, Ky.	20	54	sw.	Reno, Nev.	11	53	sw.
Louisville, Ky.	30	62	e.	St. Louis, Mo.	30	62	sw.
Lynchburg, Va.	21	59	w.	Sand Key, Fla.	13	56	nw.
Memphis, Tenn.	1	64	nw.	Sandusky, Ohio.	6	50	nw.
Mt. Tamalpais, Cal.	1	50	nw.	Sandy Hook, N. J.	5	55	e.
Do.	2	76	nw.	Do.	6	50	e.
Do.	3	56	nw.	Do.	7	50	nw.
Do.	7	50	nw.	Do.	21	50	nw.
Do.	15	57	nw.	Tatoosh Island,			
Do.	25	60	nw.	Wash.	1	50	sw.
Do.	26	53	nw.	Do.	21	52	s.
New York, N. Y.	7	68	nw.				

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by section, April, 1917.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	64.1	+1.0	Evergreen	96	29	2 stations	30	10	3.46	−0.70	Talladega	5.47	Livingston	1.37
Arizona	56.2	−2.3	3 stations	99	24†	Fort Valley	7	20	1.70	+0.80	Crown King	9.42	5 stations	0.00
Arkansas	60.4	−0.8	Huttig	90	28†	Dutton	23	9	5.69	+0.92	Alicia	12.84	Booneville	2.91
California	52.8	−4.2	Greenland Ranch	105	27	Tamarack	− 5	14	1.98	+0.19	Branscomb	10.87	5 stations	0.00
Colorado	39.7	−4.2	2 stations	88	17†	2 stations	−15	1†	2.11	+0.13	Savage Basin	9.95	2 stations	T.
Florida	70.2	+0.3	Fort Meade	97	22†	Bristol	35	10	1.56	−0.95	Miami, No. 2	4.73	Merritts Island	0.10
Georgia	65.9	+2.7	Bainbridge	97	30	Blue Ridge	26	10	3.19	−0.20	Clayton	6.21	St. George	1.13
Hawaii (March report)	69.2	+0.2	Mahukona	95	12	Volcano Observatory	44	1	13.19	+5.04	Kaueleau, Hawaii	40.10	Mahukona	0.46
Idaho	39.8	−5.1	Indian Cove	76	12	Stanley	−10	3	2.21	+0.79	Oxford Ranger Sta.	6.00	Challis	0.40
Illinois	49.9	−2.1	6 stations	87	18†	2 stations	19	9	4.76	+1.51	Carbondale	8.00	Morris	2.10
Indiana	49.8	−1.7	Shoals	89	24†	Salem	11	9	4.27	+0.89	Huntingburg	7.06	Whiting	1.72
Iowa	45.5	−3.2	Lenox	88	19	2 stations	17	2†	4.55	+1.69	Alberton	7.84	Dubuque	2.05
Kansas	52.1	−2.2	Smith Center	92	18	Colby	16	8	3.01	+0.53	Linn	6.87	Gove	0.98
Kentucky	55.8	−0.1	2 stations	90	18	Shelbyville	19	9	5.02	+0.95	Blandville	8.23	Catlettsburg	2.22
Louisiana	65.5	−1.8	Angola	93	23	3 stations	32	6†	4.38	+0.02	Kelly (near)	8.31	Paradis	1.10
Maryland-Delaware	52.4	+0.1	2 stations	90	20†	Oakland, Md	15	8	2.43	−0.77	Millsboro, Del	3.46	Delaware City, Del.	0.99
Michigan	39.4	−3.8	Morenci	82	18	Humboldt	0	8	2.71	+0.40	Lansing (Agr. Coll.)	5.59	Mancelona	0.67
Minnesota	39.5	−3.4	3 stations	81	18	4 stations	9	2†	2.32	+0.35	Lynd	4.84	Warroad	0.58
Mississippi	63.5	−0.8	Shubuta	92	29	4 stations	32	6†	4.86	−0.09	Charleston	9.28	Fruitland Park	2.05
Missouri	53.2	−2.3	St. Charles, No. 3	89	17†	Bethany, No. 2	19	9	5.97	+2.02	Koshkonong	10.82	Amoret	3.47
Montana	37.8	−3.9	2 stations	77	8	Brenner	− 4	1	1.57	+0.50	Pine Grove	4.68	Valentine	0.27
Nebraska	45.4	−3.8	Beaver City	92	20	Gordon	5	1	3.14	+0.72	Tekamah	6.30	Whitman	1.00
Nevada	43.9	−3.1	2 stations	95	25	Gold Creek	− 6	7†	0.74	−0.12	Mahoney Ranger Sta	3.68	Thorne	T.
New England	41.3	−2.1	3 stations	79	1†	Madison, Me	3	11	2.53	−0.66	Plymouth, Mass	4.88	Danielson, Conn	1.25
New Jersey	48.8	−0.2	Highwood	88	1	Culvers Lake	15	10	2.39	−1.12	Tuckerton	3.54	Phillipsburg	1.19
New Mexico	49.8	−1.8	2 stations	95	22†	Winsors Ranch	− 9	2	0.40	−0.72	Anchor Mine	3.65	21 stations	0.00
New York	42.7	−1.3	Wappinger Falls	86	1†	North Lake	5	9	2.12	−0.83	Lake Placid Club	4.39	Binghamton	0.99
North Carolina	59.9	+2.3	Kinston	96	19	Brevard	22	10	3.53	+0.09	Rockingham	5.61	Fayettesville	1.49
North Dakota	37.2	−4.5	2 stations	73	9	Howard	5	1	1.69	+0.31	McLeod	4.22	Pembina	0.24
Ohio	48.7	−1.1	2 stations	90	20	Peebles	13	9	3.38	+0.25	Marietta	4.96	Youngstown	1.27
Oklahoma	58.6	−1.4	Eldorado	95	29	2 stations	20	2†	3.43	+0.37	Durant	8.92	Lawtonka Lake	0.50
Oregon	45.7	−3.4	Grants Pass, No. 2	80	24	Crescent	9	18	3.61	+1.69	Tillamook	11.94	Fort Rock	0.26
Pennsylvania	48.5	0.0	2 stations	87	1†	Somerset	14	9	2.08	−1.37	Somerset	4.89	Milford	0.41
Porto Rico	75.4	+0.1	Canovanas	97	21	Aibonito	45	8	4.57	−0.47	Foro Negro Dam	15.36	Vieques	1.36
South Carolina	64.9	+2.5	Florence, No. 1	96	19†	Mountain Rest	28	10	3.34	+0.56	Walterboro	4.57	Charleston	0.97
South Dakota	41.1	−4.5	2 stations	89	9†	Elk Mountain	6	1	2.68	+0.86	Tyndall	4.34	Cedar Canyon	0.83
Tennessee	59.4	+1.0	Kenton	92	18	Tazewell	21	10	4.04	−0.46	Waynesboro	7.17	Johnson City	1.73
Texas	65.5	−0.5	Mission	105	28	Dalhart	19	8	2.17	−0.82	Paris	8.05	6 stations	0.00
Utah	41.8	−5.4	St. George	89	24†	East Portal	−19	4	1.81	+0.50	Utah Expt. Sta	6.04	Mosida	0.16
Virginia	55.1	+1.0	Cape Henry	94	21	Mount Weather	21	9	2.97	−0.27	Leeds Manor	4.41	Clarksville	1.05
Washington	44.9	−3.7	6 stations	73	4†	Snyders Ranch	12	1†	4.15	+2.26	Quiniault	14.42	Cowiche	0.42
West Virginia	51.7	0.0	3 stations	90	19†	Cuba	10	10	2.99	−0.53	St. Marys	5.31	Morgantown	1.29
Wisconsin	40.2	−3.3	Darlington	85	18	Deerskin Dam	− 7	8	2.56	+0.25	Hancock	5.25	New Richmond	0.48
Wyoming	34.8	−5.6	Fort Laramie	80	9	Sand Lake	−17	4	1.90	+0.56	Bechler River	4.91	Pinedale	0.37

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

[See MONTHLY WEATHER REVIEW, January, 1917, p. 40.]

TABLE I.—*Climatological data for Weather Bureau stations, April, 1917.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.											Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.					
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England.							**41.8**	**−1.7**										**75**	**2.67**	**−0.4**										**6.3**		
Eastport	76	67	85	29.81	29.89	−0.04	38.1	−0.2	60	23	44	18	10	32	26	35	32	80	3.22	+0.3	11	8,326	nw.	46	e.	6	6	12	12	6.3	17.5	....
Greenville	1,070	6	....	28.74	29.92	....	35.1	.....	62	22	43	11	10	27	29	....	....	....	3.25	.....	12	.....	.....	.....	.....	.....	6	7	17	....	10.5	....
Portland, Me	103	82	117	29.83	29.96	.00	40.2	−2.8	60	22	46	21	10	34	25	35	29	68	2.93	−0.2	13	11,155	nw.	63	nw.	4	7	8	15	6.3	1.8	....
Concord	288	70	79	29.63	29.95	− .04	40.9	−2.9	70	22	49	22	10	33	30	....	....	....	1.63	−1.2	10	4,599	nw.	33	nw.	10	10	5	15	6.1	0.3	....
Burlington	404	11	48	29.51	29.96	− .03	39.8	−0.9	68	21	47	17	10	33	23	....	....	....	2.42	+0.6	16	7,726	n.	36	s.	20	6	7	17	7.0	3.1	....
Northfield	876	12	60	.....	29.97	− .02	37.5	−2.7	64	22	45	15	10	30	31	....	....	75	2.05	−0.4	12	6,287	s.	42	n.	10	4	7	19	7.6	1.6	....
Boston	125	115	188	29.80	29.94	− .05	44.0	−1.3	72	23	50	26	10	38	23	40	36	76	2.72	−0.8	11	7,363	nw.	33	nw.	10	10	6	14	5.6	9.1	....
Nantucket	12	14	90	29.91	29.92	− .05	41.6	−2.6	67	23	48	25	9	36	26	38	36	83	4.21	+1.6	13	10,851	nw.	59	ne.	9	9	6	15	6.6	5.0	....
Block Island	26	11	46	29.90	29.93	− .05	42.0	−1.8	66	23	47	25	9	37	23	39	36	83	2.14	−1.5	14	12,605	nw.	54	n.	9	9	3	18	6.8	4.0	....
Narragansett Pier	....	9	....	.....	.....	.....	41.4	−3.2	66	23	49	19	10	34	29	....	....	....	2.94	.....	13	.....	ne.	....	.....	.....	14	2	14	....	7.0	....
Providence	160	215	251	29.76	29.94	− .04	44.6	0.0	73	23	52	24	9	37	24	38	32	68	2.62	−1.1	11	9,392	nw.	46	nw.	10	7	10	13	6.2	8.8	....
Hartford	159	122	140	29.78	29.96	− .03	45.4	−1.3	73	1	54	26	10	37	31	39	33	67	2.47	−1.1	11	5,615	nw.	34	nw.	10	7	12	11	5.7	0.4	....
New Haven	106	117	155	29.85	29.97	− .02	45.8	−0.6	71	23	54	26	9	38	26	41	36	74	3.00	−0.6	14	6,441	nw.	41	nw.	10	8	11	11	5.6	4.2	....
Middle Atlantic States.							**51.3**	**+0.6**										**66**	**2.12**	**−1.0**										**5.3**		....
Albany	97	102	115	29.85	29.96	−0.04	45.2	−0.6	75	1	53	26	10	37	36	38	31	61	1.38	−1.0	8	6,072	nw.	27	s.	20	10	12	8	5.1	T.	....
Binghamton	871	10	69	29.02	29.96	− .06	44.5	+0.1	74	18	53	21	9	36	40	....	....	....	0.99	−1.3	10	5,040	nw.	31	nw.	10	5	11	14	6.6	4.8	....
New York	314	414	454	29.61	29.95	− .05	47.2	−0.9	79	1	55	25	9	39	31	40	33	63	2.35	−1.0	12	12,942	nw.	68	nw.	7	6	10	14	6.7	6.5	....
Harrisburg	374	94	104	29.58	29.98	− .04	51.4	+0.7	81	1	60	28	9	42	29	43	34	56	1.65	−0.8	9	6,126	nw.	29	e.	5	10	9	11	5.5	0.8	....
Philadelphia	117	123	190	29.85	29.98	− .03	52.3	+1.5	81	1	61	28	9	43	27	46	43	77	2.47	−0.4	9	8,211	nw.	35	nw.	7	10	10	10	5.2	7.0	....
Reading	325	81	98	29.62	29.98	.....	50.8	.....	82	1	60	27	10	41	29	43	35	60	2.12	−1.1	11	6,415	nw.	48	e.	5	8	11	11	5.7	3.0	....
Scranton	805	111	119	29.10	29.97	− .04	47.6	+0.5	79	1	56	24	9	39	38	41	35	67	1.06	−1.6	9	5,786	nw.	32	nw.	10	7	11	12	6.5	T.	....
Atlantic City	52	37	48	29.92	29.98	− .02	48.2	+0.6	72	1	55	27	10	41	28	43	38	74	2.01	−1.0	6	6,163	nw.	34	se.	5	10	15	5	4.9	5.0	....
Cape May	18	13	49	29.97	30.00	+ .01	48.9	+0.5	71	22	56	28	9	42	25	44	....	....	2.54	−0.4	8	6,749	e.	45	se.	5	12	13	5	4.7	4.3	....
Sandy Hook	22	10	57	29.93	29.95	.....	46.2	.....	77	1	53	28	9	40	32	42	39	82	1.91	.....	8	11,384	nw.	55	e.	5	10	9	11	5.2	5.5	....
Trenton	190	159	183	29.75	29.96	.....	49.1	.....	80	1	58	25	9	40	31	42	36	67	2.29	−1.0	11	9,120	nw.	55	w.	21	11	10	9	5.4	6.2	....
Baltimore	123	100	113	29.85	29.98	− .03	53.8	+0.8	85	1	63	28	9	45	28	45	37	57	2.21	−1.1	9	9,125	nw.	44	e.	5	11	9	10	5.1	3.0	....
Washington	112	62	85	29.85	29.97	− .05	54.2	+1.1	85	21	64	28	9	44	32	46	38	60	2.16	−1.1	11	5,762	nw.	40	nw.	7	12	11	7	4.8	1.5	....
Lynchburg	681	153	188	29.23	29.98	− .04	57.4	+1.8	90	19	69	30	14	45	38	49	43	65	3.10	−0.1	10	5,629	e.	59	w.	21	11	13	6	5.5	0.4	....
Norfolk	91	170	205	29.89	29.99	− .02	57.6	+1.6	86	21	67	34	9	48	29	49	43	69	2.61	−1.2	6	10,295	se.	64	w.	21	13	12	5	4.3	T.	....
Richmond	141	11	52	29.83	29.98	− .04	57.4	+0.2	90	19	68	31	10	46	37	48	42	64	2.56	−0.9	11	6,589	se.	40	sw.	21	10	10	10	5.2	T.	....
Wytheville	2,293	49	55	27.61	29.98	− .05	52.7	+0.7	80	20	64	29	10	41	37	45	39	64	2.40	−1.3	10	5,427	w.	37	w.	5	19	5	6	3.6	T.	....
South Atlantic States.							**64.1**	**+3.0**										**68**	**2.83**	**−0.6**										**3.5**		
Asheville	2,255	70	84	27.64	29.98	−0.05	56.8	+2.9	84	19	69	30	10	44	36	47	39	59	2.80	−1.2	8	6,238	nw.	33	s.	1	16	8	6	3.8	T.	....
Charlotte	773	153	161	29.14	29.98	− .05	62.3	+3.1	89	19	74	36	10	51	32	52	44	60	2.54	−0.9	9	8,151	sw.	60	sw.	30	19	5	6	3.6	0.0	....
Hatteras	11	12	50	29.97	29.98	− .03	59.2	+1.2	80	19	66	40	10	52	24	54	50	78	2.08	−2.3	8	11,499	ne.	50	s.	8	16	11	3	4.2	0.0	....
Manteo	12	5	43	.....	.....	.....	57.2	.....	87	19	68	32	15	46	....	....	....	....	5.28	+0.7	7	.....	sw.	....	.....	.....	16	7	7	....	0.0	....
Raleigh	376	103	110	29.57	29.98	− .05	60.6	+1.6	91	19	73	33	10	49	35	51	45	63	4.92	+1.4	9	6,275	sw.	45	w.	21	12	13	5	4.3	0.0	....
Wilmington	78	81	91	29.90	29.99	− .04	63.4	+3.0	90	20	74	38	10	53	31	56	52	73	2.55	−0.3	7	5,865	w.	47	sw.	8	14	10	6	3.8	0.0	....
Charleston	48	11	92	29.95	30.00	− .03	67.2	+3.4	92	20	76	45	10	59	28	60	56	72	0.97	−2.0	6	7,813	s.	41	sw.	5	18	10	2	2.7	0.0	....
Columbia, S. C	351	41	57	29.60	29.97	− .06	65.8	+5.4	91	19	76	39	10	55	32	54	46	56	2.82	0.0	8	5,397	sw.	46	sw.	5	18	9	3	3.1	0.0	....
Augusta	180	62	77	29.78	29.98	− .05	67.0	+3.8	91	19	79	41	10	55	35	59	55	72	4.43	+0.9	6	3,983	se.	38	w.	5	20	3	7	3.3	0.0	....
Savannah	65	150	194	29.93	30.00	− .03	68.8	+4.1	91	20	79	47	10	59	27	60	56	73	1.92	−1.1	9	7,431	sw.	44	nw.	5	19	8	3	3.0	0.0	....
Jacksonville	43	200	245	29.97	30.02	− .02	69.6	+2.0	89	30	78	49	9	61	24	61	57	72	0.82	−1.9	7	8,481	sw.	50	sw.	8	17	7	6	3.6	0.0	....
Florida Peninsula.							**73.2**	**−0.6**										**71**	**2.15**	**+0.3**										**3.4**		
Key West	22	10	64	29.96	29.98	−0.04	74.9	−0.6	83	30	80	66	7	69	17	68	64	70	1.07	−0.2	3	7,719	e.	43	nw.	13	17	11	2	3.5	0.0	....
Miami	25	71	79	29.98	30.01	− .01	72.0	−2.2	81	9	78	52	7	66	24	65	61	69	3.74	+1.2	9	7,275	e.	33	sw.	13	19	6	5	3.7	0.0	....
Sand Key	23	39	72	29.94	29.97	− .05	74.2	−0.8	82	26	76	64	8	72	15	68	64	72	1.76	.....	3	10,725	e.	56	nw.	13	21	7	2	2.6	0.0	....
Tampa	35	79	96	29.98	30.02	− .04	71.6	+1.0	88	27	82	52	7	61	28	64	60	72	1.65	−0.2	5	4,863	ne.	35	sw.	8	14	13	3	3.7	0.0	....
East Gulf States.							**65.3**	**+0.7**										**68**	**3.70**	**−0.4**										**4.0**		
Atlanta	1,174	190	216	28.76	29.99	−0.04	63.7	+2.6	88	30	74	38	9	53	31	53	45	56	3.17	−0.5	6	8,253	w.	48	sw.	5	14	7	9	4.2	0.0	....
Macon	370	78	87	29.59	29.98	− .05	66.2	+3.1	92	30	79	40	10	54	35	56	49	61	3.94	+0.5	8	4,162	s.	28	w.	5	19	7	4	3.2	0.0	....
Thomasville	273	49	58	29.70	30.00	− .03	68.1	+1.4	90	29	80	42	10	56	31	59	54	68	1.55	−2.1	9	3,251	sw.	28	sw.	5	13	12	5	4.2	0.0	....
Pensacola	56	149	185	29.95	30.01	− .01	66.1	−1.6	79	30	72	44	9	60	20	60	56	74	2.14	−1.0	7	9,713	s.	63	sw.	5	13	12	5	4.0	0.0	....
Anniston	741	9	57	29.22	30.01	− .02	62.6	+2.2	88	30	76	33	10	49	38	....	....	....	4.17	+0.5	7	4,514	nw.	30	e.	4	13	14	3	3.9	0.0	....
Birmingham	700	11	48	29.25	30.01	− .01	64.0	+0.5	86	27	76	38	10	52	34	53	46	59	4.52	+0.8	8	5,322	s.	29	s.	1	14	9	7	3.9	0.0	....
Mobile	57	125	161	29.94	30.00	− .02	66.6	+0.6	84	24	75	43	10	58	28	59	55	74	2.50	−1.8	7	7,829	s.	32	nw.	12	14	12	4	3.8	0.0	....
Montgomery	223	100	112	29.76	30.01	− .02	65.8	+0.6	89	29	77	40	10	54	33	56	49	61	2.66	−1.6	7	4,916	sw.	29	w.	5	12	12	6	4.2	0.0	....
Corinth	469	6	....	.....	.....	.....	60.9	.....	87	18	74	32	10	47	40	....	....	....	5.12	.....	6	.....	s.	....	.....	.....	15	10	5	....	0.0	....
Jackson	304	5	....	.....	.....	.....	64.4	.....	88	29	76	37	10	53	37	....	....	....	5.12	.....	10	.....	s.	....	.....	.....	10	14	6	....	0.0	....
Meridian	375	85	93	29.60	29.99	− .03	63.4	−0.7	86	29	75	35	10	52	35	55	50	67	4.16	−0.9	9	4,251	s.	35	sw.	4	11	14	5	4.3	0.0	....
Vicksburg	247	65	74	29.73	30.01	+ .01	63.9	−1.3	85	29	73	40	3	55	28	57	52	72	7.75	+2.6	8	5,649	se.	31	nw.	4	12	9	9	5.0	0.0	....
New Orleans	51	76	84	29.94	29.99	− .01	68.2	+0.3	86	29	77	48	9	60	24	63	61	83	4.11	−0.8	7	5,686	se.	24	nw.	8	14	13	3	3.7	0.0	....
West Gulf States.							**64.5**	**−1.1**										**68**	**2.92**	**−0.6**										**4.6**		
Shreveport	249	77	93	29.70	29.97	0.00	63.8	−2.0	85	25	74	39	9	53	30	56	50	65	2.34	−1.2	10	6,535	se.	42	s.	19	11	9	10	4.9	0.0	....
Bentonville	1,303	11	44	28.56	29.93	− .03	56.2	−0.7	82	24	67	30	9	45	33	....	....	....	5.88	+2.0	12	5,526	se.	26	sw.	18	11	10	9	4.8	0.0	....
Fort Smith	457	79	94	29.46	29.94	− .02	60.1	−1.6	87	24	71	37	9	49	32	52	46	66	3.14	−0.8	12	7,591	e.	56	w.	30	11	7	12	5.4	0.0	....
Little Rock	357	139	147	29.60	29.97	− .01	61.2	−1.5	83	17	71	37	9	52	28	54	49	69	3.91	−0.6	10	6,332	s.	39	nw.	30	11	9	10	4.9	0.0	....
Brownsville	57	4	26	.....	.....	.....	74.4	.....	98	1	85	48	6	64	34	....	....	....	0.43	.....	2	.....	s.	....	.....	.....	....	....	....	....	0.0	....
Corpus Christi	20	69	77	29.92	29.94	− .01	70.8	−0.1	91	28	76	50	6	65	23	65	62	79	1.07	−0.7	4	12,130	se.	48	se.	27	9	9	12	5.2	0.0	....
Dallas	512	109	117	29.40	29.94	.....	63.5	.....	86	24	74	41	8	53	34	....	....	....	5.24	.....	8	9,191	s.	42	nw.	30	10	12	8	4.7	0.0	....
Fort Worth	670	106	114	29.21	29.92	− .02	63.8	−1.5	88	24	74	39	9	53	32	54	47	60	4.11	+1.5	7	10,313	se.	40	s.	19	12	11	7	4.4	0.0	....
Galveston	54	106	114	29.92	29.98	+ .01	67.8	−0.9	83	12	72	51	9	63	19	62	58	77	1.45	−1.7	9	10,174	se.	35	sw.	20	16	8	6	3.7	0.0	....
Houston	138	111	121	29.81	29.96	.....	67.9	−1.7	85	25	77	**45**	9	59	26	....	....	....	2.30	.....	10	7,924	se.	29	se.	19	12	9	9	4.5	0.0	....
Palestine	510	64	72	29.43	29.96	.00	64.0	−1.9	84	29	74	**39**	3	54	35	56	50	66	3.49	−0.6	8	6,664	se.	36	se.	19	13	7	10	5.0	0.0	....
Port Arthur	34	58	66	29.93	29.97	.....	65.9	.....	82	30	73	43	9	59	24	62	60	86	3.05	.....	8	8,838	se.	34	s.	27	13	10	7	4.4	0.0	....
San Antonio	701	119	132	29.19	29.92	− .01	69.0	0.0	93	28	81	44	5	57	34	58	50	59	0.28	−2.7	4	6,849	s.	**44**	se.	27	18	8	4	3.0	0.0	....
Taylor	582	55	63	29.36	29.97	+ .02	66.2	−1.3	87	28	78	**41**	5	54	36	....	....	....	2.56	−1.4	6	8,780	se.	**44**	sw.	**27**	**13**	10	7	4.2	0.0	....

TABLE I.—*Climatological data for Weather Bureau stations, April, 1917*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.								Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*		°*F.*	°*F.*	%	*In.*	*In.*		*Miles*										*0–10*	*In.*	*In.*
Ohio Valley and Tennessee.							**54.2**	**−0.4**											**65**	**3.76**	**+0.2**										**5.7**		
Chattanooga	762	189	213	29.18	29.99	−0.04	61.9	+1.9	86	18	73	36	9	50	32		51	43	55	3.89	−0.5	9	6,829	w.	40	nw.	5	15	9	6	4.2	0.0	....
Knoxville	906	93	100	28.93	29.98	− .05	60.4	+3.0	87	18	73	34	10	48	36		50	40	52	2.13	−2.5	11	4,389	sw.	28	sw.	1	17	8	5	3.9	0.0	....
Memphis	399	76	97	29.59	30.01	+ .01	61.7	−0.1	83	18	70	37	9	53	32		52	45	58	4.13	−0.7	10	7,235	s.	64	nw.	1	12	12	6	4.8	0.0	....
Nashville	546	168	191	29.41	30.00	− .01	59.7	+0.6	86	18	71	32	9	48	36		50	42	59	4.05	−0.3	9	7,816	e.	49	sw.	1	15	6	9	4.5	0.0	....
Lexington	989	193	230	28.92	30.00	− .02	53.8	+0.1	83	18	64	22	9	44	30					3.97	+0.6	12	11,113	se.	54	sw.	20	11	11	8	5.1	0.4	....
Louisville	525	219	255	29.42	30.01	.00	54.8	−1.4	86	18	65	26	9	44	32		46	38	60	4.93	+0.9	12	10,112	s.	62	e.	30	9	9	12	5.8	3.2	....
Evansville	431	139	175	29.52	29.99	− .01	55.9	−0.5	84	24	66	30	9	46	32		48	41	63	5.12	+1.7	11	9,514	ne.	58	sw.	30	6	16	8	5.5	T.	....
Indianapolis	822	194	230	29.10	29.99	− .01	49.2	−3.2	82	18	58	25	14	40	31		43	37	66	4.25	+0.8	11	10,668	s.	52	nw.	5	5	7	18	7.1	0.2	....
Terre Haute	575	96	129	29.35	29.97	.....	51.0	.....	84	18	60	28	14	42	28		46	41	72	3.95	.....	12	9,000	nw.	43	sw.	30	4	12	14	6.9	0.5	....
Cincinnati	628	11	51	29.31	30.00	− .01	51.2	−1.1	84	18	61	21	9	41	33		44	38	65	4.07	+1.1	8	7,021	ne.	38	sw.	30	9	8	13	6.1	0.3	....
Columbus	824	173	222	29.11	30.02	− .02	49.6	−1.4	82	20	59	24	9	40	35		44	29	72	3.15	+0.3	12	7,926	sw.	38	nw.	6	6	10	14	6.4	0.3	....
Dayton	899	181	216	29.01	29.97	.....	49.7	−2.0	82	18	59	25	9	40	31		45	41	77	3.68	+0.8	12	8,633	sw.	48	sw.	30	6	10	14	6.6	0.5	....
Pittsburgh	842	353	410	29.09	30.01	− .01	49.6	−1.4	81	20	59	21	9	40	34		43	38	72	2.20	−0.7	12	9,043	nw.	54	nw.	18	6	11	13	6.1	0.7	....
Elkins	1,940	41	50	27.93	30.00	− .03	49.2	+0.5	84	20	61	21	9	37	44		42	37	69	2.72	−0.6	13	3,555	w.	27	w.	2	4	11	15	6.7	2.7	....
Parkersburg	638	77	84	29.35	30.01	− .02	52.6	−0.4	86	20	63	26	14	42	40		45	40	69	4.29	+1.4	11	4,868	nw.	30	w.	2	9	12	9	5.6	0.2	....
Lower Lake Region.							**43.3**	**−1.9**											**73**	**3.06**	**+0.7**										**6.7**		
Buffalo	767	247	280	29.14	29.99	−0.02	40.4	−1.9	71	20	48	22	9	32	30		36	33	77	2.45	0.0	14	11,946	sw.	50	sw.	1	4	11	15	6.9	1.5	....
Canton	448	10	61	29.46	29.95	.....	40.5	−2.0	68	21	48	19	9	33	28					1.92	−0.3	12	8,212	w.	59	sw.	2	8	8	14	6.5	1.8	....
Oswego	335	76	91	29.60	29.97	− .04	40.4	−2.8	72	20	46	23	9	34	26		38	34	78	3.21	+1.0	14	8,176	w.	33	nw.	9	7	7	16	6.5	2.2	....
Rochester	523	97	113	29.41	30.00	− .01	42.8	−1.1	75	20	50	24	9	35	30		38	32	70	2.80	+0.4	9	7,125	w.	36	w.	21	9	7	14	6.3	2.3	....
Syracuse	597	97	113	29.33	29.98	− .03	42.4	−2.0	71	21	50	22	9	35	30		38	32	70	2.27	0.0	15	9,079	nw.	43	sw.	2	9	5	16	6.6	3.0	....
Erie	714	130	166	29.20	29.98	− .04	43.8	−0.9	77	20	51	24	9	36	32		40	35	74	3.01	+0.6	15	10,384	w.	62	se.	5	2	15	13	6.4	8.7	....
Cleveland	762	190	201	29.17	30.00	− .02	45.4	−0.6	80	20	53	26	9	38	35		40	35	71	3.24	+0.9	13	9,980	nw.	48	nw.	6	3	11	16	7.1	T.	....
Sandusky	629	62	103	29.30	30.00	− .02	45.1	−2.2	81	20	52	26	9	38	33		40	36	72	3.66	+1.1	11	9,902	sw.	50	nw.	6	2	10	18	7.7	T.	....
Toledo	628	208	243	29.31	30.00	− .01	45.2	−2.1	80	18	53	24	9	37	37		40	35	69	3.39	+1.1	10	10,709	sw.	47	sw.	20	5	11	14	6.2	T.	....
Fort Wayne	856	113	124	29.07	30.01	.....	46.4	−2.9	83	18	55	23	14	37	33		41	35	69	3.47	.....	10	7,880	nw.	39	s.	20	6	5	19	6.8	T.	....
Detroit	730	218	245	29.20	30.00	− .02	43.6	−1.9	76	20	51	25	9	36	33		39	35	77	4.61	+2.3	12	8,475	w.	39	sw.	11	6	10	14	6.7	T.	....
Upper Lake Region.							**38.2**	**−2.6**											**76**	**2.74**	**+0.4**										**6.2**		
Alpena	609	13	92	29.35	30.03	+0.01	36.4	−1.6	78	20	43	18	10	30	40		33	29	78	2.02	−0.2	11	9,840	nw.	45	se.	25	7	12	11	5.6	6.3	....
Escanaba	612	54	60	29.38	30.06	+ .04	34.6	−2.6	57	11	41	16	9	28	24		31	28	81	1.72	−0.4	10	7,160	ne.	38	n.	5	9	8	13	5.8	6.6	....
Grand Haven	632	54	92	29.31	30.00	− .01	40.6	−3.4	72	18	48	21	9	33	28		36	32	74	4.40	+2.0	12	9,400	n.	35	n.	5	7	14	9	5.4	T.	....
Grand Rapids	707	70	87	29.23	30.01	− .01	43.1	−3.1	76	20	52	22	9	35	29		38	32	68	4.03	+1.6	14	5,435	nw.	28	nw.	18	5	14	11	6.4	0.1	....
Houghton	684	62	99	29.33	30.08	+ .06	33.8	−3.1	58	19	40	16	9	28	24					1.69	−0.3	10	7,114	e.	33	w.	21	11	9	10	5.4	5.6	....
Lansing	878	11	62	29.04	30.00	.....	42.4	−3.2	76	20	52	21	9	33	31		38	33	75	5.59	+3.0	14	5,436	n.	30	nw.	18	4	10	16	7.0	1.3	....
Ludington	637	60	66	29.31	30.02	.....	38.6	.....	66	20	45	20	9	32	27		35	31	76	2.85	.....	14	8,357	n.	36	n.	6	8	10	12	5.6	0.4	....
Marquette	734	77	111	29.28	30.10	+ .08	33.4	−4.1	54	19	38	20	9	29	25		30	26	75	1.75	−0.2	14	6,848	nw.	33	e.	10	8	6	16	6.6	10.7	T.
Port Huron	638	70	120	29.29	30.00	− .02	40.5	−1.7	73	20	48	23	10	33	36		37	34	79	2.52	+0.4	13	8,703	ne.	36	ne.	6	8	8	14	6.6	1.2	....
Saginaw	641	48	82	29.30	30.01	.....	41.4	.....	76	20	49	21	9	34	29		38	34	76	3.29	+0.6	13	7,641	nw.	32	e.	25	3	9	18	7.7	0.6	....
Sault Sainte Marie	614	11	61	29.34	30.05	+ .02	33.8	−1.9	60	30	40	15	9	28	27		31	27	78	1.01	−1.1	10	7,862	nw.	38	w.	2	11	5	14	5.9	1.6	....
Chicago	823	140	310	29.11	30.01	+ .01	44.8	−1.1	82	18	51	30	13	39	31		39	34	69	2.58	−0.3	14	10,514	ne.	46	sw.	20	7	7	16	6.6	T.	....
Green Bay	617	109	144	29.35	30.02	+ .01	39.4	−1.3	69	20	47	22	8	32	32		35	30	75	2.32	−0.1	11	8,709	ne.	36	s.	20	4	10	16	7.0	2.5	....
Milwaukee	681	119	133	29.26	30.01	+ .02	40.7	−1.1	71	20	47	26	13	34	27		37	34	80	3.98	+1.3	10	8,751	ne.	42	e.	24	8	11	11	6.2	T.	....
Duluth	1,133	11	47	28.84	30.09	+ .08	33.2	−5.2	49	17	39	18	8	27	20		30	25	74	1.39	−0.8	7	9,722	ne.	42	ne.	24	8	12	10	5.9	7.1	....
North Dakota.							**37.6**	**−3.0**											**72**	**1.61**	**−0.2**										**6.4**		
Moorhead	940	8	57	29.05	30.09	+0.10	39.2	−2.2	58	23	48	21	14	30	28		35	31	78	1.90	−0.4	10	5,930	n.	30	se.	9	11	9	10	5.0	5.2	....
Bismarck	1,674	8	57	28.28	30.10	+ .13	38.5	−4.1	68	9	48	17	2	29	35		33	27	70	1.87	0.0	11	7,056	e.	43	e.	17	5	8	17	7.1	6.0	....
Devils Lake	1,482	11	44	28.47	30.08	+ .09	36.1	−2.1	56	20	45	17	1	27	27		31	26	70	1.40	−0.6	6	8,256	ne.	30	ne.	6	2	13	15	6.9	6.4	....
Grand Forks	835	12	89	.....	.....	.....	37.5	.....	57	23	46	20	2	29	26		35	.....	.....	1.37	.....	8	.....	n.	.....	.....	15	8	7	.....	.....	0.7	....
Williston	1,872	41	48	28.03	30.05	+ .09	36.8	−3.7	62	22	46	14	1	28	31		32	27	71	1.28	0.0	9	6,676	e.	36	e.	12	6	9	15	6.5	1.6	....
Upper Mississippi Valley.							**47.8**	**−2.7**											**70**	**3.90**	**+0.9**										**6.5**		
Minneapolis	918	10	208	29.02	30.01	.....	41.9	.....	78	18	50	25	8	34	33		.....	.....	.....	1.70	−0.7	12	8,209	ne.	37	n.	20	7	6	17	7.0	0.5	....
St. Paul	837	201	236	29.10	30.03	+0.04	42.2	−3.5	78	18	50	26	8	34	30		.....	.....	.....	1.65	−0.7	11	8,429	n.	40	s.	9	4	15	11	6.5	T.	....
La Crosse	714	11	48	29.24	30.02	+ .04	44.9	−2.4	78	18	54	27	9	36	30		.....	.....	.....	3.35	+1.1	13	4,230	ne.	22	s.	20	7	7	16	6.5	0.0	....
Madison	974	70	78	28.96	30.03	+ .04	42.4	−2.1	78	18	50	24	14	34	31	37	33	73		3.29	+0.9	14	7,948	n.	35	s.	10	4	6	20	7.2	1.4	T.
Wausau	1,247	4	.....	28.68	30.03	.....	39.2	.....	69	20	48	20	14	30	34	.....	.....	.....	.....	2.86	.....	10	.....	nw.	.....	.....	.....	9	10	11	5.6	8.6	....
Charles City	1,015	10	49	28.91	30.00	+ .02	44.2	−2.1	83	18	53	24	2	35	35	39	35	74		2.94	+0.1	14	5,474	ne.	30	sw.	10	3	13	14	6.9	5.5	....
Davenport	606	71	79	29.33	29.99	+ .01	46.8	−3.4	82	18	56	28	8	38	33	41	36	70		4.40	+1.5	14	7,057	e.	32	e.	7	6	7	17	7.4	2.1	....
Des Moines	861	84	97	29.05	29.97	.00	46.8	−3.8	83	18	55	25	8	38	35	42	36	69		5.52	+2.5	13	6,660	n.	35	s.	10	5	6	19	7.4	4.8	....
Dubuque	698	81	96	29.26	30.02	+ .04	46.4	−2.5	83	18	55	27	9	38	30	40	33	63		2.05	−0.9	15	5,701	s.	27	n.	1	7	9	14	6.6	1.4	T.
Keokuk	614	64	78	29.30	29.98	.00	48.7	−3.3	82	18	57	28	9	40	31	43	38	70		3.36	0.0	13	7,283	ne.	38	sw.	20	9	11	10	5.5	2.5	....
Cairo	356	87	93	29.58	29.97	− .02	58.0	−0.3	83	18	67	33	8	49	28	50	44	64		6.96	+3.4	10	7,764	s.	47	n.	8	10	9	11	5.4	T.	....
Peoria	609	11	45	29.32	29.99	.00	47.4	−3.5	84	18	56	23	9	39	29	42	38	74		4.54	+1.3	15	7,515	ne.	34	sw.	20	8	10	12	6.3	T.	....
Springfield, Ill	644	10	91	29.28	29.96	− .02	50.0	−2.0	84	18	59	28	9	40	29	44	38	70		3.77	+0.5	16	8,094	ne.	32	sw.	20	8	6	16	6.5	0.5	....
Hannibal	534	74	109	29.40	29.98	.00	50.1	−3.5	84	18	59	29	9	41	30					6.38	+3.1	16	9,000	ne.	48	e.	7	6	10	14	6.4	2.2	....
St. Louis	567	265	303	29.35	29.96	− .02	53.7	−2.4	84	23	63	30	9	45	26	48	44	75		4.64	+1.1	14	11,247	s.	62	sw.	30	8	13	9	5.7	1.0	....
Missouri Valley.							**47.9**	**−2.6**											**70**	**3.96**	**+1.1**										**6.3**		
Columbia, Mo.	781	11	84	29.12	29.96	−0.02	52.0	−2.3	86	23	62	28	9	42	33		.....	.....	.....	4.64	+0.9	17	8,061	ne.	38	sw.	20	8	6	16	6.6	T.	....
Kansas City	963	161	181	28.90	29.95	− .01	52.0	−2.3	85	23	61	30	8	43	30	45	39	67		6.87	+3.6	14	10,843	s.	44	n.	7	11	4	15	5.8	2.0	....
St. Joseph	967	11	49	28.91	29.95	.....	50.7	.....	85	22	60	29	8	42	33	43	37	66		4.77	.....	13	8,347	ne.	38	nw.	20	8	10	12	5.6	1.8	....
Springfield, Mo.	1,324	98	104	28.55	29.95	− .02	54.0	−1.7	82	23	64	30	9	44	27	46	38	62		4.63	+0.8	12	9,937	se.	42	w.	30	15	9	6	4.1	0.9	....
Iola	984	11	50	28.86	29.91	− .04	53.8	−0.4	86	23	65	27	9	43	39					4.61	+1.8	9	6,372	s.	31	n.	7	8	13	9	5.4	T.	....
Topeka	987	85	101	.....	.....	.....	51.9	−1.8	85	22	62	28	9	42	37					4.35	+1.6	12	9,315	ne.	37	nw.	20	8	7	15	6.1	T.	....
Drexel	1,299	10	54	28.56	29.97	.....	46.2	.....	84	18	57	21	8	36	34	40	35	74		4.53	.....	12	9,862	ne.	45	sw.	10	3	7	20	7.6	8.1	....
Lincoln	1,189	11	84	28.67	29.95	+ .01	48.8	−1.9	85	18	60	27	8	38	36	41	34	64		4.26	+1.5	11	9,627	n.	46	nw.	20	6	10	14	6.5	0.9	....
Omaha	1,105	115	122	28.78	29.97	+ .02	47.9	−2.6	85	18	57	28	8	39	32	42	36	69		3.96	+1.0	10	6,780	nw.	34	nw.	20	6	10	14	6.4	1.6	....
Valentine	2,598	47	54	27.26	30.01	+ .07	40.7	−4.7	79	9	51	22	8	31	40	36	31	76		2.36	0.0	6	7,843	nw.	41	nw.	24	7	12	11	6.1	10.2	....
Sioux City	1,135	94	164	28.76	29.99	+ .04	45.0	−3.5	77	10	54	25	8	36	37	40	36	74		3.52	+0.8	11	9,460	ne.	47	nw.	25	7	8	15	6.9	5.7	....
Huron	1,306	59	74	28.62	30.04	+ .08	41.8	−2.8	72	9	51	23	15	33	38	37	32	74		3.01	+0.4	11	8,247	nw.	39	nw.	10	7	8	15	6.5	T.	....
Pierre	1,572	70	75	28.34	30.03	+ .08	42.5	−4.0	84	9	52	22	4	33	46	37	31	70		2.39	+0.4	12	7,787	nw.	44	nw.	25	7	5	18	6.9	9.3	....
Yankton	1,233	49	57	28.65	29.98	+ .03	44.3	−3.1	78	10	54	25	8	35	40					2.89	+0.1	12	7,118	nw.	36	s.	17	4	9	17	7.4	1.0	....

TABLE I.—*Climatological data for Weather Bureau stations, April, 1917*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.							
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*									*0–10*	*In.*	*In.*
Northern Slope.							**38.9**	**−3.9**											**67**	**1.98**	**+0.4**											**6.5**		
Billings	3,140	5	....	.....	.....	.....	42.0	.....	76	8	54	16	16	31	48	.....	.....	.....	.....	.....	.....	1.99	.....	10	.....	ne.	.....	.....	.....	7	10	13	.....	.....	....
Havre	2,505	11	44	27.34	30.01	+0.08	39.4	−3.3	67	8	49	21	1	30	37	35	29	69	1.35	+0.3	10	5,488	e.	30	w.	4	6	12	12	6.6	4.3	....
Helena	4,110	87	114	25.74	29.98	+ .01	38.8	−3.2	67	8	48	18	1	30	32	32	26	64	1.51	+0.4	12	6,264	sw.	39	s.	11	2	12	16	7.3	6.4	T.	....
Kalispell	2,962	11	34	26.89	29.98	+ .02	39.6	−2.9	57	22	49	14	1	30	29	34	27	66	1.26	+0.2	9	3,671	w.	26	n.	27	3	14	13	6.9	0.4	....	....
Miles City	2,371	48	55	27.47	30.06	+ .10	42.8	−1.9	72	8	53	24	1	32	37	37	33	74	1.02	−0.2	12	5,272	e.	34	nw.	23	5	19	6	5.7	2.1	....	....
Rapid City	3,259	50	58	26.58	30.05	+ .10	39.6	−3.9	78	9	50	13	1	30	48	33	26	62	3.95	+1.6	16	6,686	n.	39	nw.	24	5	8	17	7.3	22.6	T.	....
Cheyenne	6,088	84	101	23.91	29.96	+ .05	36.4	−5.2	66	9	47	6	1	26	44	30	23	64	1.75	−0.1	12	11,065	w.	47	nw.	5	4	14	12	6.9	15.4	T.	....
Lander	5,372	60	68	24.56	29.96	+ .02	38.0	−4.2	65	8	50	11	4	26	40	31	24	65	2.42	0.0	14	3,599	sw.	40	sw.	2	5	15	10	6.2	20.0	....	....
Sheridan	3,790	10	47	26.06	30.00	.....	40.1	.....	74	8	50	21	1	30	46	34	28	68	1.12	.....	16	5,453	nw.	38	nw.	23	7	7	16	6.7	5.5	....	....
Yellowstone Park	6,200	11	48	23.78	30.00	+ .04	30.6	−6.4	53	8	39	10	3	22	31	26	22	73	2.64	+1.3	17	6,293	s.	36	nw.	2	5	12	13	6.3	22.7	7.3	....
North Platte	2,821	11	51	27.04	29.99	+ .07	44.8	−4.2	81	9	57	22	8	33	48	37	30	66	1.95	−0.2	9	7,045	n.	35	n.	19	12	8	10	5.3	2.6	....	....
Middle Slope.							**30.8**	**−2.9**											**60**	**1.80**	**−0.4**											**5.5**		
Denver	5,292	106	113	24.64	29.93	+0.03	44.0	−3.7	76	22	55	17	1	33	45	36	27	61	0.75	−1.4	8	6,095	se.	39	n.	19	7	10	13	6.1	7.2	....	....
Pueblo	4,685	80	86	25.20	29.90	+ .02	46.8	−3.7	80	22	61	21	8	33	49	36	26	55	1.39	0.0	10	5,034	nw.	40	w.	18	13	8	9	4.7	7.6	....	....
Concordia	1,392	50	58	28.46	29.95	+ .02	51.0	−2.6	87	22	62	28	2	40	39	43	34	60	2.60	+0.2	12	8,735	nw.	45	nw.	20	5	15	10	6.6	0.1	....	....
Dodge City	2,509	11	51	27.34	29.94	+ .04	51.4	−3.0	83	17	64	22	5	39	48	43	37	65	1.45	−0.4	10	10,117	n.	60	se.	17	12	9	9	5.1	0.6	....	....
Wichita	1,358	139	158	28.47	29.90	− .03	54.2	−2.4	84	23	65	30	5	44	36	45	37	58	2.52	−0.2	10	12,722	s.	48	s.	3	10	11	9	5.6	T.	....	....
Altus	1,410	5	....	.....	.....	.....	60.6	.....	90	22	74	30	5	47	52	.....	.....	.....	3.05	.....	5	.....	se.	.....	.....	.....	17	4	9	.....	0.0	....	....
Muskogee	652	4	....	.....	.....	.....	54.7	.....	80	22	63	33	2	47	30	.....	.....	.....	6.63	.....	8	.....	s.	.....	.....	.....	13	3	14	.....	0.0	....	....
Oklahoma	1,214	10	47	28.65	29.93	+ .01	57.6	−2.0	86	22	69	32	5	46	35	48	40	58	2.11	−0.7	9	13,740	s.	50	s.	3	9	16	5	4.8	0.0	....	....
Southern Slope.							**61.7**	**−0.7**											**42**	**1.33**	**−0.6**											**2.5**		
Abilene	1,738	10	52	28.10	29.89	−0.01	64.0	−0.4	95	24	77	34	5	51	42	50	36	45	0.93	−1.4	5	9,991	s.	40	nw.	30	19	7	4	3.0	0.0	....	....
Amarillo	3,676	10	49	26.18	29.89	+ .02	54.8	+0.2	90	23	69	26	8	40	44	42	32	52	0.71	−1.1	6	10,157	s.	42	nw.	3	24	6	0	3.1	T.	....	....
Del Rio	944	64	71	28.92	29.89	.00	70.6	+0.6	95	29	82	43	5	59	34	.....	.....	.....	2.36	+0.4	4	9,347	e.	48	e.	18	19	11	0	2.4	0.0	....	....
Roswell	3,566	75	85	26.26	29.83	− .02	57.3	−3.3	87	26	74	28	5	41	47	41	19	28	0.00	−0.5	0	7,523	s.	42	nw.	11	22	8	0	1.5	0.0	....	....
Southern Plateau.							**55.3**	**−2.5**											**39**	**0.36**	**0.0**											**2.6**		
El Paso	3,762	110	133	26.09	29.81	−0.02	62.3	−1.5	87	25	76	36	5	48	41	43	18	21	T.	−0.2	0	9,684	w.	52	sw.	29	23	6	1	1.6	0.0	....	....
Santa Fe	7,013	57	66	23.14	29.81	− .03	46.1	−1.5	70	24	58	20	4	35	34	34	18	38	0.15	−0.7	4	7,615	sw.	40	sw.	15	9	17	4	4.4	0.5	....	....
Flagstaff	6,908	8	57	23.26	29.86	+ .02	38.1	−4.1	66	25	52	9	20	24	48	31	.....	.....	4.47	.....	8	.....	w.	42	sw.	9	20	5	5	.....	35.9	....	....
Phoenix	1,108	76	81	28.72	29.87	.00	64.2	−2.4	93	25	80	37	2	49	43	52	42	53	1.22	+0.8	6	4,105	w.	25	sw.	27	23	4	3	2.7	0.0	....	....
Yuma	141	9	54	29.73	29.88	− .01	68.5	−1.6	98	25	84	42	1	53	43	51	34	36	0.24	+0.1	2	4,707	w.	30	n.	3	28	1	1	0.7	0.0	....	....
Independence	3,910	11	42	25.90	29.87	− .03	52.6	−4.1	84	25	69	21	17	36	41	42	30	47	0.17	0.0	3	.....	w.	.....	.....	.....	14	10	6	3.8	T.	....	....
Needles, Cal	488	4	....	29.32	29.83	.....	68.0	.....	103	25	85	38	2	51	49	.....	.....	.....	0.80	.....	1	.....	s.	.....	.....	.....	21	8	1	.....	0.0	....	....
Middle Plateau.							**44.8**	**−3.8**											**50**	**1.07**	**−0.1**											**5.1**		
Reno	4,532	74	81	25.41	29.95	−0.02	45.6	−1.7	76	24	58	20	16	33	42	36	26	50	0.28	−0.3	3	6,548	w.	53	sw.	11	11	12	7	4.8	0.7	....	....
Tonopah	6,090	12	20	23.98	29.91	− .06	43.3	−4.0	71	25	54	19	15	33	30	34	22	47	1.22	−0.5	5	7,294	nw.	48	w.	14	14	12	4	3.9	10.3	....	....
Winnemucca	4,344	18	56	25.55	29.96	.00	44.4	−2.7	74	24	58	15	16	31	40	35	25	55	0.68	−0.2	9	5,634	sw.	30	sw.	11	6	10	14	6.4	2.7	....	....
Modena	5,479	10	43	24.52	29.88	.00	42.6	−4.3	75	25	57	16	1	28	46	33	20	51	1.17	+0.4	6	7,978	sw.	48	sw.	8	14	11	5	3.7	5.0	....	....
Salt Lake City	4,360	163	203	25.54	29.91	− .01	45.6	−4.5	73	8	55	24	3	37	30	37	27	50	1.49	−0.8	9	6,598	nw.	40	w.	14	6	12	12	6.0	5.4	....	....
Grand Junction	4,602	82	96	25.29	29.86	− .02	47.3	−5.9	77	22	59	22	4	36	37	37	24	46	1.59	+0.8	7	6,489	se.	37	w.	15	11	7	12	5.6	1.8	....	....
Northern Plateau.							**44.9**	**−4.2**											**63**	**2.46**	**+1.1**											**7.4**		
Baker	3,471	48	53	26.38	29.99	−0.01	40.2	−3.3	63	24	49	24	3	32	31	35	28	65	1.59	+0.6	12	4,983	se.	26	n.	27	3	13	14	6.4	0.8	....	....
Boise	2,739	78	86	27.12	29.99	+ .01	46.4	−4.1	66	7	56	27	3	37	28	39	30	59	3.13	+2.0	12	5,108	se.	28	nw.	25	3	10	17	7.5	3.0	....	....
Lewiston	757	40	48	29.17	29.99	.00	48.6	−4.3	67	4	57	32	13	40	31	.....	.....	.....	2.81	+1.7	17	3,456	e.	28	ne.	27	1	8	21	7.9	T.	....	....
Pocatello	4,477	60	68	25.39	29.95	+ .01	40.6	−6.2	67	25	49	17	3	32	33	35	28	64	1.83	−0.2	14	7,169	se.	36	sw.	8	2	13	15	7.1	8.6	....	....
Spokane	1,929	101	110	27.92	29.99	.00	44.5	−3.2	60	22	52	31	1	37	27	38	31	63	1.71	+0.4	13	5,436	sw.	26	sw.	23	1	11	18	7.8	1.0	....	....
Walla Walla	991	57	65	28.92	30.00	− .01	49.0	−3.8	68	4	57	33	15	41	27	42	35	62	3.68	+2.0	20	4,592	s.	25	se.	7	2	11	17	7.5	0.3	....	....
North Pacific Coast Region.							**47.0**	**−2.6**											**82**	**5.97**	**+0.5**											**7.7**		
North Head	211	11	56	29.78	30.02	−0.03	44.6	−2.9	60	28	48	37	12	41	16	44	43	94	6.06	+2.8	25	13,735	s.	72	se.	1	1	6	23	8.6	0.0	....	....
North Yakima	1,071	4	....	.....	.....	.....	47.6	.....	68	26	60	25	1	36	35	.....	.....	.....	0.59	.....	8	.....	nw.	.....	.....	.....	4	13	13	.....	0.0	....	....
Port Angeles	42	8	48	29.96	29.99	.....	44.6	.....	66	28	51	31	1	38	29	.....	.....	.....	1.95	.....	19	3,833	nw.	23	ne.	13	4	9	17	7.0	0.0	....	....
Seattle	125	215	250	29.90	30.03	.00	46.8	−2.4	64	28	53	36	15	41	23	43	39	77	4.48	+1.8	22	6,986	s.	42	sw.	22	1	8	21	8.2	0.0	....	....
Tacoma	213	113	120	29.79	30.02	− .01	46.8	−2.1	64	28	53	33	22	40	28	45	43	88	5.78	+3.0	24	4,115	sw.	26	sw.	21	1	10	19	8.1	T.	....	....
Tatoosh Island	109	7	57	29.87	29.97	− .03	44.2	−5.2	56	28	48	35	1	40	15	43	41	89	10.76	+4.4	26	9,861	e.	52	s.	21	4	9	17	7.0	T.	....	....
Medford	1,425	4	....	.....	.....	.....	49.8	.....	79	24	61	29	18	38	40	.....	.....	.....	1.25	.....	13	.....	nw.	.....	.....	.....	3	9	18	.....	0.0	....	....
Portland, Oreg	153	68	106	29.87	30.03	− .03	49.4	−1.8	67	28	56	37	15	43	23	44	39	73	5.36	+2.3	24	4,745	sw.	26	w.	10	1	4	25	8.4	0.0	....	....
Roseburg	510	9	57	29.51	30.07	.00	50.0	−0.9	76	24	59	33	15	41	33	44	39	71	3.37	+0.9	21	2,719	nw.	20	sw.	11	1	22	7	6.3	T.	....	....
Middle Pacific Coast Region.							**53.3**	**−0.3**											**67**	**1.20**	**−0.9**											**3.7**		
Eureka	62	73	89	30.04	30.11	0.00	49.0	−0.5	62	22	55	34	15	43	21	46	43	82	3.78	−0.2	14	5,995	se.	37	n.	28	6	13	11	6.2	0.0	....	....
Mount Tamalpais	2,375	11	18	27.56	30.05	.00	48.8	−0.7	68	4	55	31	15	43	19	42	34	64	1.28	−0.2	9	14,289	nw.	76	nw.	2	13	11	6	4.1	0.0	....	....
Point Reyes Light	490	7	18	29.49	30.01	− .02	49.2	+0.6	63	4	54	40	16	45	18	.....	.....	.....	1.19	.....	12	14,454	nw.	61	nw.	26	13	8	9	4.3	0.0	....	....
Red Bluff	332	50	56	29.64	30.00	− .03	57.6	−1.5	83	25	68	32	16	47	33	48	37	53	0.91	−0.9	5	4,762	se.	27	nw.	26	17	5	8	4.2	0.0	....	....
Sacramento	69	106	117	29.95	30.02	+ .01	57.8	−0.2	83	25	69	36	16	46	31	50	42	61	0.62	−1.4	4	6,193	s.	32	nw.	28	20	7	3	2.8	0.0	....	....
San Francisco	155	209	213	29.88	30.05	.00	55.1	+1.4	76	4	62	43	16	48	25	49	45	75	0.33	−1.5	5	6,451	sw.	37	sw.	11	26	2	2	1.6	0.0	....	....
San Jose	141	12	110	29.90	30.05	.....	55.6	−1.1	80	21	68	35	17	43	37	.....	.....	.....	0.26	−1.2	5	4,652	nw.	25	nw.	14	20	5	5	3.0	0.0	....	....
South Pacific Coast Region.							**57.4**	**−0.5**											**67**	**0.46**	**−0.6**											**3.3**		
Fresno	327	89	98	29.65	30.01	+0.02	59.3	−1.9	87	25	73	38	15	46	33	49	39	56	0.21	−0.5	3	6,359	nw.	30	nw.	7	20	9	1	2.5	0.0	....	....
Los Angeles	338	159	191	29.63	30.00	+ .01	57.9	+0.3	84	5	67	42	18	49	27	50	44	68	0.46	−0.7	5	4,532	sw.	35	nw.	2	15	10	5	3.7	0.0	....	....
San Diego	87	62	70	29.90	29.99	.00	57.0	−1.2	79	5	63	44	1	51	26	52	47	76	1.06	+0.3	6	5,299	w.	43	s.	16	13	8	9	4.5	0.0	....	....
San Luis Obispo	201	32	40	29.85	30.07	+ .02	55.6	+0.4	85	5	68	32	17	44	38	48	43	68	0.11	−1.4	3	3,620	nw.	24	w.	14	21	8	1	2.4	0.0	....	....
West Indies.																																			
San Juan, P. R	82	8	54	29.88	29.97	−0.01	76.3	.....	90	23	82	65	7	70	23	.....	.....	.....	2.82	−1.0	16	8,380	se.	32	e.	2	8	15	7	5.3	0.0	....	....
Panama Canal.																																			
Balboa Heights	118	7	97	29.74	29.86	.....	80.3	.....	94	25	88	69	25	72	25	73	71	81	2.24	−0.6	6	6,221	n.	26	n.	27	1	28	1	5.9	0.0	....	....
Colon	25	5	71	29.84	29.88	.....	79.2	.....	90	14	82	72	27	76	15	75	73	80	1.87	−2.3	11	8,269	n.	27	nw.	28	5	16	9	5.8	0.0	....	....
Alaska.																																			
Juneau	80	11	49	.....	.....	.....	41.9	.....	64	29	51	25	3	33	29	36	30	67	1.69	.....	7	2,857	s.	16	se.	9	9	10	11	5.5	1.0	....	....

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during April, 1917, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex	30			0.33														0.33			
Albany, N. Y	20			0.59														0.29			
Alpena, Mich	5			0.66														*			
Amarillo, Tex	10			0.29														0.22			
Anniston, Ala	4			2.68														0.55			
Asheville, N. C	25			0.34														0.28			
Atlanta, Ga	4			1.90														0.32			
Atlantic City, N. J	13			0.54														0.12			
Augusta, Ga	4			1.61														0.52			
Baker, Oreg	11–12			0.43														*			
Baltimore, Md	5			1.17														0.42			
Bentonville, Ark	27	6:02 p. m.	7:40 p. m.	0.92	6:27 p. m.	6:57 p. m.	0.10	0.12	0.26	0.38	0.48	0.56	0.73								
Binghamton, N. Y	5			0.32														0.10			
Birmingham, Ala	4			2.69														0.54			
Bismarck, N. Dak	16			0.89														*			
Block Island, R. I	6			0.57														0.17			
Boise, Idaho	27–28			1.06														*			
Boston, Mass	6			1.19														0.33			
Buffalo, N. Y	5			0.73														0.14			
Burlington, Vt	20			0.58														*			
Cairo, Ill	1	12:15 a. m.	1:10 p. m.	3.61	4:25 a. m. 9:12 a. m.	4:51 a. m. 10:03 a. m.	1.12 2.48	0.06 0.16	0.13 0.29	0.21 0.37	0.41 0.48	0.50 0.53	0.53 0.58	0.65	0.75	0.80	0.85	0.90			
Canton, N. Y	26			0.41														0.16			
Charles City, Iowa	28–29			0.94														*			
Charleston, S. C	14			0.40														0.22			
Charlotte, N. C	8			0.60														0.37			
Chattanooga, Tenn	28	1:25 p. m.	2:16 p. m.	0.40	1:49 p. m.	1:58 p. m.	0.01	0.19	0.35												
Cheyenne, Wyo	28–29			0.36														*			
Chicago, Ill	30			0.79														0.32			
Cincinnati, Ohio	2			1.04														0.44			
Cleveland, Ohio	30			0.50														0.30			
Columbia, Mo	30			0.96														0.34			
Columbia, S. C	5			0.87														0.38			
Columbus, Ohio	5			1.06														0.19			
Concord, N. H	6			0.65														*			
Concordia, Kans	28			0.85														0.30			
Corpus Christi, Tex	20	5:01 a. m.	8:25 a. m.	0.93	5:01 a. m.	5:41 a. m.	0.00	0.15	0.31	0.42	0.49	0.55	0.59	0.65	0.73						
Dallas, Tex	27–28			2.36														*			
Davenport, Iowa	24			1.24														0.63			
Dayton, Ohio	30	5:20 p. m.	6:32 p. m.	0.58	5:35 p. m.	5:47 p. m.	0.03	0.17	0.46	0.52											
Del Rio, Tex	18	7:45 p. m.	10:20 p. m.	1.37	8:06 p. m.	8:41 p. m.	0.05	0.10	0.18	0.30	0.44	0.52	0.58	0.65							
	27	3:24 p. m.	4:15 p. m.	0.60	3:26 p. m.	3:48 p. m.	0.01	0.15	0.20	0.33	0.49	0.55									
Denver, Colo	28–29			0.22														*			
Des Moines, Iowa	28			1.64														0.38			
Detroit, Mich	18	7:17 p. m.	9:20 p. m.	0.85	8:06 p. m.	8:15 p. m.	0.04	0.43	0.61												
Devils Lake, N. Dak	24			0.75														*			
Dodge City, Kans	12			0.37														0.19			
Drexel, Nebr	28			1.67														0.41			
Dubuque, Iowa	28			0.51														0.25			
Duluth, Minn	25			0.67														*			
Eastport, Me	9–10			1.51														*			
Elkins, W. Va	18			0.24														0.16			
El Paso, Tex	10			T.														T.			
Erie, Pa	18			0.75														0.35			
Escanaba, Mich	18			0.48														*			
Eureka, Cal	11			0.54														0.20			
Evansville, Ind	1			2.54														0.45			
Flagstaff, Ariz	16–17			1.90														*			
Fort Smith, Ark	29–30	11:10 p. m.	D. N. a. m.	0.64	12:17 a. m.	12:42 a. m.	0.04	0.06	0.25	0.44	0.50	0.58									
Fort Wayne, Ind	5			1.15														0.21			
Fort Worth, Tex	27	6:24 p. m.	10:55 p. m.	1.67	8:14 p. m.	8:45 p. m.	0.04	0.14	0.35	0.57	0.79	0.98	1.15	1.18							
Fresno, Cal	28			0.16														0.16			
Galveston, Tex	4			0.56														0.35			
Grand Haven, Mich	18			1.08														0.57			
Grand Junction, Colo	26			0.29														0 12			
Grand Rapids, Mich	18			0.92														0.47			
Green Bay, Wis	30			0.57														*			
Hannibal, Mo	29			0.90														0.41			
Harrisburg, Pa	5			1.01														0.22			
Hartford, Conn	6			1.08														0.21			
Hatteras, N. C	8			0.57														0.43			
Havre, Mont	23			0.56														0.27			
Helena, Mont	12			0.16														0.08			
Houghton, Mich	25–26			0.65														*			
Houston, Tex	12	D. N. a. m.	5:15 a. m.	0.74	4:46 a. m.	4:57 a. m.	0.02	0.13	0.50	0.71											
Huron, S. Dak	24			0.48														0.26			
Independence, Cal	28			0.07														*			
Indianapolis, Ind	19			0.56														0.42			
Iola, Kans	27	3:40 p. m.	6:55 p. m.	1.27	4:14 p. m.	4:34 p. m.	0.02	0.23	0.42	0.64	0.71										
Jacksonville, Fla	13			0.38														0.22			
Juneau, Alaska	10			0.18														0.15			
Kalispell, Mont	23			0.37														*			
Kansas City, Mo	17	D. N. a. m.	6:35 a. m.	0.87	2:22 a. m.	2:45 a. m.	0.03	0.15	0.22	0.36	0.49	0.54									
	27	D. N. a. m.	2:25 p. m.	2.03	3:33 a. m.	4:37 a. m.	0.30	0.10	0.14	0.16	0.23	0.27	0.31	0.53	0.60	0.70	0.78	0.91	1.18		
Keokuk, Iowa	19			0.34														0.28			
Key West, Fla	8			0.88														0.68			
Knoxville, Tenn	4			0.78														0.17			
La Crosse, Wis	18			0.90														0.43			
Lander, Wyo	26–27			0.76														*			
Lansing, Mich	19			1.01														0.58			
Lewiston, Idaho	14			0.61														0.15			
Lexington, Ky	1			1.26														0.33			
Lincoln, Nebr	27–28			1.74														*			
Little Rock, Ark	7	10:55 a. m.	4:00 p. m.	0.84	1:52 p. m.	2:12 p. m.	0.33	0.09	0.26	0.35	0.46										
Los Angeles, Cal	9			0.26														0.25			
Louisville, Ky	1			1.57														0.38			
Ludington, Mich	30			0.75														0.14			
Lynchburg, Va	5			1.69														0.41			
Macon, Ga	4–5	1:09 p. m.	7:40 a. m.	2.99	6:58 a. m.	7:33 a. m.	2.36	0.06	0.07	0.19	0.31	0.39	0.50	0.63							
Madison, Wis	18			0.76														0.34			
Marquette, Mich	25–26			0.84														*			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during April, 1917, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Memphis, Tenn.	7			1.31														0.41			
	7	7:50 p. m.	D. N. p. m.	1.00	10:12 p. m.	10:34 p. m.	0.36	0.18	0.37	0.43	0.52	0.57									
Meridian, Miss.	17	5:05 p. m.	6:15 p. m.	0.79	5:08 p. m.	5:30 p. m.	0.01	0.19	0.51	0.65	0.72	0.77									
Miami, Fla.	13	1:05 p. m.	2:40 p. m.	1.88	1:12 p. m.	1:47 p. m.	0.02	0.19	0.49	0.84	1.10	1.36	1.63	1.79							
		3:05 p. m.	4:25 p. m.	1.34	3:06 p. m.	3:58 p. m.	T.	0.30	0.67	0.85	0.85	0.85	0.85	0.93	1.01	1.14	1.27	1.32			
Milwaukee, Wis.	18			1.00														0.30			
Minneapolis, Minn.	24			0.59														0.21			
Mobile, Ala.	4–5	7:50 p. m.	D. N. a. m.	1.24	10:44 p. m.	11:18 p. m.	0.44	0.07	0.10	0.18	0.20	0.33	0.51	0.59							
	8	D. N. a. m.	D. N. a. m.	0.57	12:34 a. m.	12:45 a. m.	0.04	0.10	0.51	0.53											
Modena, Utah.	28–29			0.90														*			
Montgomery, Ala.	8			0.62														0.48			
Moorhead, Minn.	24			0.72														*			
Mount Tamalpais, Cal.	11			0.65														0.19			
Nantucket, Mass.	6			1.31														0.60			
Nashville, Tenn.	1			1.50														0.76			
Needles, Cal.																					
New Haven, Conn.	6			1.07														0.33			
New Orleans, La.	4	6:35 p. m.	D. N. p. m.	2.29	7:42 p. m.	8:20 p. m.	0.01	0.05	0.12	0.25	0.51	0.85	1.14	1.19	1.27						
New York, N. Y.	5			0.47														0.18			
Norfolk, Va.	5			1.19														0.28			
Northfield, Vt.	6–7			0.59														*			
North Head, Wash.	10			0.65														0.16			
North Platte, Nebr.	19–20			1.02														*			
Oklahoma, Okla.	30			0.77														0.44			
Omaha, Nebr.	28			1.24														0.42			
Oswego, N. Y.	5–6			0.74														*			
Palestine, Tex.	4	4:05 a. m.	9:15 a. m.	1.08	7:13 a. m.	7:42 a. m.	0.07	0.11	0.17	0.31	0.56	0.74	0.80								
	11	7:03 p. m.	9:50 p. m.	1.02	7:39 a. m.	8:04 p. m.	0.06	0.32	0.48	0.60	0.66	0.78									
	19–20	11:45 p. m.	3:40 a. m.	0.74	12:08 a. m.	12:23 a. m.	0.03	0.12	0.48	0.59											
Parkersburg, W. Va.	30			0.33														0.27			
Pensacola, Fla.	21	12:35 p. m.	1:55 p. m.	0.56	1:03 p. m.	1:19 p. m.	0.01	0.15	0.40	0.48	0.52										
Peoria, Ill.	23–24			0.90														0.32			
Philadelphia, Pa.	5			1.18														0.25			
Phoenix, Ariz.	27			0.24														0.09			
Pierre, S. Dak.	24			0.47														0.36			
Pittsburgh, Pa.	18			0.50														0.36			
Pocatello, Idaho.	14–15			0.72														*			
Point Reyes Light, Cal.	11			0.50														0.14			
Port Angeles, Wash.	24			0.45														0.17			
Port Arthur, Tex.	12	D. N. a. m.	7:40 a. m.	1.19	6:09 a. m.	6:35 a. m.	0.31	0.06	0.19	0.29	0.53	0.68	0.70								
Port Huron, Mich.	20			0.27														0.26			
Portland, Me.	6			1.66														0.25			
Portland, Oreg.	1			0.57														0.17			
Providence, R. I.	9			0.88														*			
Pueblo, Colo.	13			0.26														0.09			
Raleigh, N. C.	8	3:00 p. m.	8:25 p. m.	1.69	3:51 p. m.	4:34 p. m.	0.27	0.10	0.19	0.25	0.36	0.43	0.47	0.54	0.63	0.71					
Rapid City, S. Dak.	15–16			1.39														*			
Reading, Pa.	19			0.30														0.30			
Red Bluff, Cal.	8			0.56														0.37			
Reno, Nev.	28			0.13														*			
Richmond, Va.	5			0.92														0.16			
Rochester, N. Y.	20			0.32														0.23			
Roseburg, Oreg.	30			0.50														0.18			
Roswell, N. Mex.	‡			‡																	
Sacramento, Cal.	22			0.39														0.09			
Saginaw, Mich.	19			0.25														0.17			
St. Joseph, Mo.	28			0.75														0.39			
St. Louis, Mo.	27			1.28														0.61			
St. Paul, Minn.	24			0.65														0.24			
Salt Lake City, Utah.	18			0.38														*			
San Antonio, Tex.	19–20			0.21														0.18			
San Diego, Cal.	16			0.86														0.22			
Sand Key, Fla.	13	12:20 p. m.	12:53 p. m.	0.68	12:32 p. m.	12:48 p. m.	0.03	0.11	0.32	0.59	0.65										
Sandusky, Ohio.	1			0.86														0.24			
Sandy Hook, N. J.	21			0.22														0.18			
San Francisco, Cal.	11			0.25														0.14			
San Jose, Cal.	14			0.06														0.06			
San Luis Obispo, Cal.	16			0.09														0.04			
Santa Fe, N. Mex.	1			0.06														*			
Sault Ste. Marie, Mich.	25–26			0.30														*			
Savannah, Ga.	8			0.66														0.39			
Scranton, Pa.	5–6			†0.55														*			
Seattle, Wash.	10			0.37														0.12			
Sheridan, Wyo.	28			0.27														*			
Shreveport, La.	4			1.20														0.55			
Sioux City, Iowa.	17	7:01 p. m.	11:45 p. m.	0.85	10:36 p. m.	11:21 p. m.	0.07	0.10	0.30	0.35	0.46	0.51	0.55	0.59	0.65	0.73					
Spokane, Wash.	7–8			0.48														*			
Springfield, Ill.	27			1.21														0.25			
Springfield, Mo.	1			1.17														0.55			
Syracuse, N. Y.	5–6			0.68														*			
Tacoma, Wash.	4			0.72														0.14			
Tampa, Fla.	5			0.46														0.46			
Tatoosh Island, Wash.	1			0.96														0.24			
Taylor, Tex.	19	12:31 a. m.	D. N. a. m.	1.25	1:11 a. m.	2:09 a. m.	0.01	0.08	0.17	0.26	0.34	0.45	0.61	0.68	0.72	0.83	0.95	1.18			
Terre Haute, Ind.	19			0.38														0.28			
Thomasville, Ga.	8			0.65														0.39			
Toledo, Ohio.	20			0.33														0.33			
Tonopah, Nev.	16–17			0.94														*			
Topeka, Kans.	27–28	7:45 p. m.	7:40 a. m.	1.97	2:35 a. m.	2:52 a. m.	0.69	0.09	0.25	0.42	0.47										
Valentine, Nebr.	19			0.83														0.11			
Vicksburg, Miss.*	1	9:10 p. m.	10:40 p. m.	1.71	9:24 p. m.	10:03 p. m.	0.01	0.06	0.31	0.71	0.85	1.05	1.29	1.44	1.68						
	4	10:49 a. m.	8:30 p. m.	1.65	12:10 p. m.	12:48 p. m.	0.09	0.12	0.31	0.44	0.55	0.56	0.60	0.66	0.76						
	7	4:54 p. m.	7:55 p. m.	1.12	5:55 p. m.	6:46 p. m.	0.07	0.15	0.41	0.44	0.45	0.48	0.51	0.65	0.76	0.85	0.91	0.97			
Walla Walla, Wash.	8			0.80														†0.22			
Washington, D. C.	5			0.78														0.24			
Wausau, Wis.	25			0.79														*			
Wichita, Kans.	30			0.81														†0.29			
Williston, N. Dak.	23			0.60														0.35			
Wilmington, N. C.	8			0.88														0.37			
Winnemucca, Nev.	27–28			0.23														*			
Wytheville, Va.	28–29			0.55														†0.23			
Yankton, S. Dak.	19			0.79														0.34			
Yellowstone Park, Wyo.	25–26			0.59														*			

* Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, April, 1917.*

Stations.	Altitude above M. S. L.* Jan. 1, 1916.	Pressure.			Temperature.						Precipitation.		
		Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.62	29.76	−0.13	37.5	+3.0	42.8	32.2	62	22	8.79	+4.63	3.0
Sydney, C. B. I.	48	29.84	29.88	− .01	38.0	+3.0	45.5	30.5	60	22	4.06	+0.21	1.0
Halifax, N. S.	88	29.75	29.86	− .10	40.7	+2.9	49.6	31.8	68	25	5.30	+1.12	4.7
Yarmouth, N. S.	65	29.79	29.86	− .10	38.6	−0.3	44.6	32.7	55	22	5.69	+2.30	9.1
Charlottetown, P. E. I.	38	29.82	29.86	− .04	37.5	+2.3	43.6	31.5	58	28	3.56	+0.91	2.8
Chatham, N. B.	28	29.89	29.91	+0.01	37.0	+1.5	44.0	29.9	58	16	5.26	+2.63	13.6
Father Point, Que.	20	29.93	29.95	+ .02	34.1	+0.9	39.1	29.1	48	18	3.29	+1.71	14.7
Quebec, Que.	296	29.62	29.95	− .04	35.9	+0.8	42.9	29.0	56	11	1.26	−0.83	0.9
Montreal, Que.	187	29.73	29.94	− .06	39.2	−0.5	46.0	32.5	64	18	2.37	+0.13	2.0
Stonecliffe, Ont.	489	29.34	29.96	− .06	39.2	+1.3	46.5	31.9	64	16	1.76	+0.20	4.6
Ottawa, Ont.	236	29.69	29.96	−0.06	39.5	−0.5	47.0	31.9	62	18	2.95	+1.45	9.7
Kingston, Ont.	285	29.66	29.98	− .04	40.8	+0.8	47.2	34.5	60	19	2.36	+0.57	1.6
Toronto, Ont.	379	29.57	29.99	− .03	41.1	+0.3	48.8	33.4	65	20	3.36	+0.99	2.3
White River, Ont.	1,244	28.69	30.04	± .00	28.3	−4.7	38.9	17.8	54	− 7	0.96	−0.29	2.6
Port Stanley, Ont.	592	29.33	29.99	− .03	39.5	−1.5	47.3	31.8	67	18	4.60	+2.13	2.7
Southampton, Ont.	656	29.28			37.5	−1.2	45.0	29.9	73	18	3.69	+1.89	10.0
Parry Sound, Ont.	688	29.28	29.98	−0.04	37.7	+0.1	46.5	28.9	70	13	2.84	+0.93	3.9
Port Arthur, Ont.	644	29.37	30.11	+ .08	33.5	0.0	42.0	25.0	50	12	0.68	−1.04	0.7
Winnipeg, Man.	760	29.29	30.15	+ .13	35.0	−0.9	44.3	25.7	58	15	0.22	−0.83	0.8
Minnedosa, Man.	1,090	28.27	30.14	+ .13	31.7	−4.3	40.7	22.8	49	7	0.86	−0.20	8.6
Qu'Appelle, Sask.	2,115	27.77	30.07	+0.08	32.0	−5.4	40.1	23.9	50	3	1.73	+0.68	15.1
Medicine Hat, Alberta.	2,144	27.66	29.96	+ .04	40.7	−3.8	52.3	29.2	64	20	0.83	+0.09	5.0
Swift Current, Sask.	2,392	27.40	30.02	+ .06	35.3	−6.0	44.4	26.2	58	4	1.10	+0.17	9.0
Calgary, Alberta.	3,428	26.41	30.00	+ .10	35.9	−3.7	48.0	23.8	62	10	0.90	+0.26	7.8
Banff, Alberta.	4,521	25.32	29.97	+ .07	31.8	−3.5	41.2	22.4	49	− 5	0.78	−0.30	7.8
Edmonton, Alberta.	2,150	27.68	30.00	+0.11	34.3	−5.6	44.1	24.6	52	7	1.05	+0.17	10.3
Prince Albert, Sask.	1,450	28.52	30.12	+ .14	30.8	−5.3	40.6	20.9	52	−10	1.04	+0.21	10.4
Battleford, Sask.	1,592	28.31	30.10	+ .13	32.3	−4.9	40.9	23.8	50	2	1.23	+0.76	11.0
Kamloops, B. C.	1,262	28.68	29.98	+ .05	46.5	−2.4	58.0	34.9	68	19	0.80	+0.41	1.2
Victoria, B. C.	230	29.72	29.97	− .04	46.5	−0.3	51.9	41.1	65	35	2.41	+0.04	0.0
Barkerville, B. C.	4,180	25.58	29.94	+0.08	31.3	−1.8	40.2	22.4	46	5	1.20	−0.62	12.0
Hamilton, Bermuda.	151	29.86	30.03	− .02	63.1	−0.8	68.3	57.9	72	51	1.88	−2.30	0.0

* See description of Table III in this REVIEW, January, p. 40.

LATE REPORT—MARCH, 1917.

St. Johns, N. F.	125	29.66	29.80	−0.08	25.3	−2.4	32.1	18.5	50	2	3.05	−1.71	14.4

Chart I. Hydrographs of Several Principal Rivers, April, 1917.

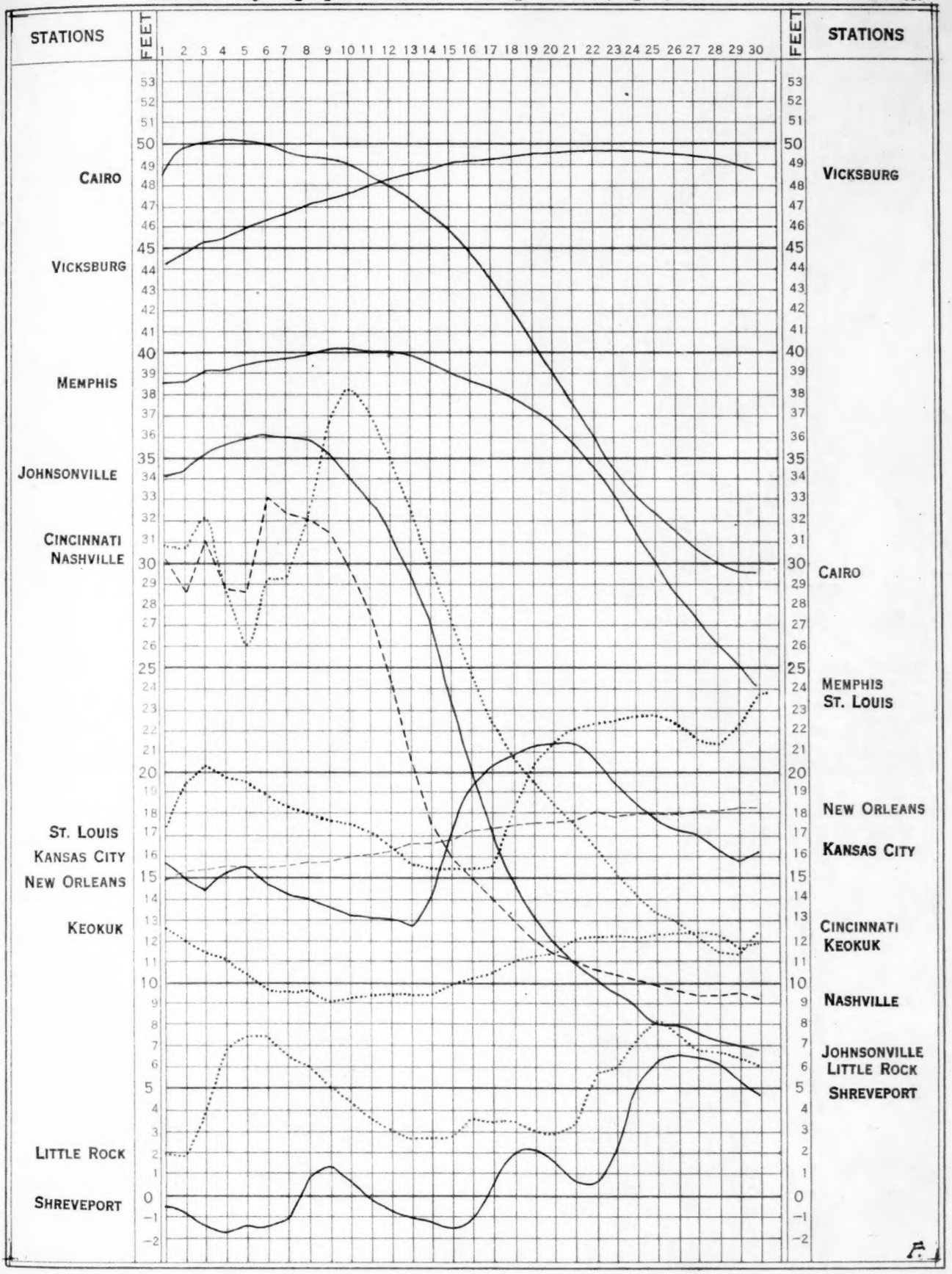

STATIONS
FEET
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 −1 −2
CAIRO
VICKSBURG
MEMPHIS
JOHNSONVILLE
CINCINNATI
NASHVILLE
ST. LOUIS
KANSAS CITY
NEW ORLEANS
KEOKUK
LITTLE ROCK
SHREVEPORT
VICKSBURG
CAIRO
MEMPHIS
ST. LOUIS
NEW ORLEANS
KANSAS CITY
CINCINNATI
KEOKUK
NASHVILLE
JOHNSONVILLE
LITTLE ROCK
SHREVEPORT

Chart II. Tracks of Centers of High Areas, April, 1917.

(Plotted by Charles A. Donnel.)

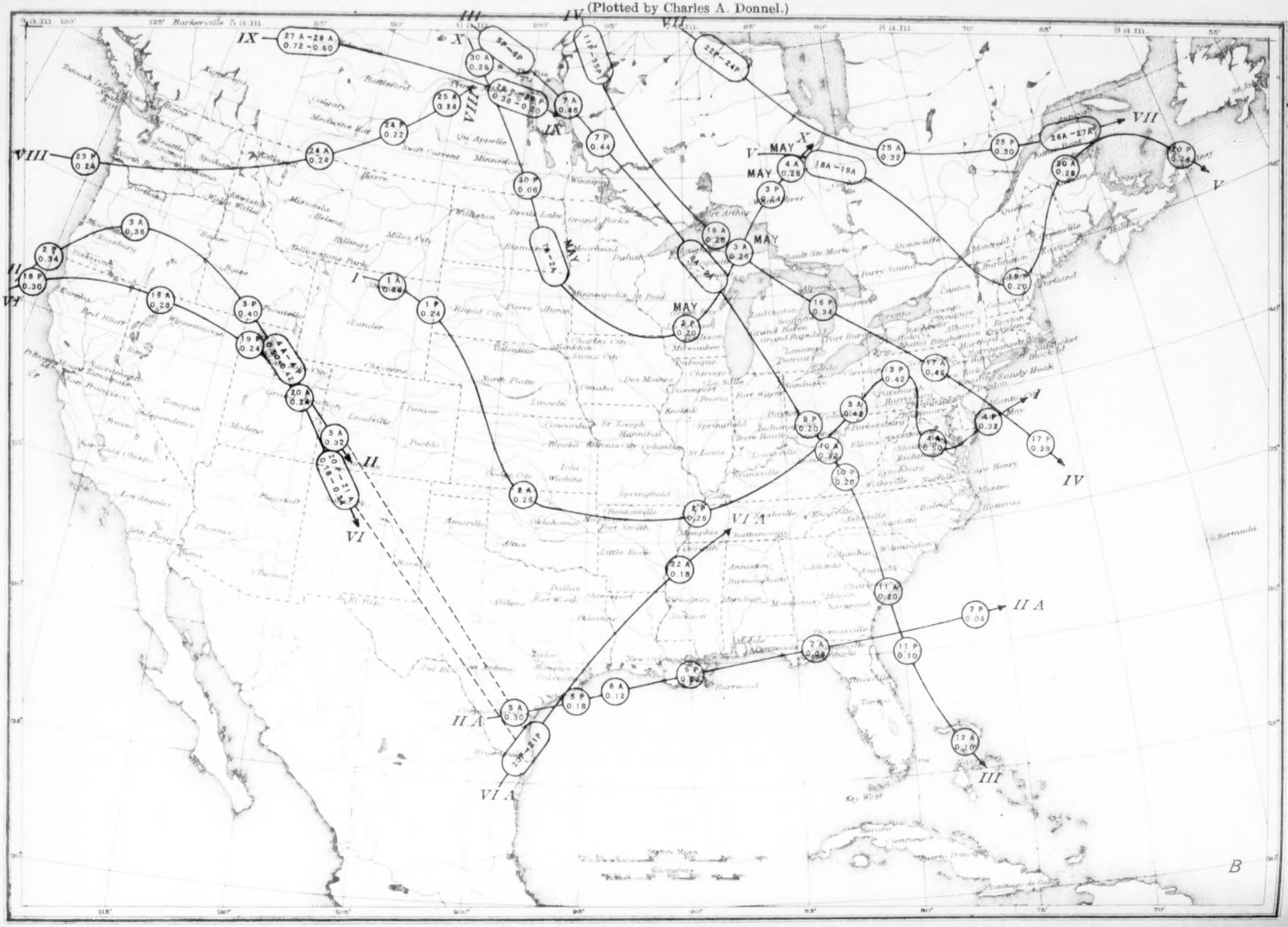


Chart III. Tracks of Centers of Low Areas, April, 1917.

(Plotted by Charles A. Donnel.)

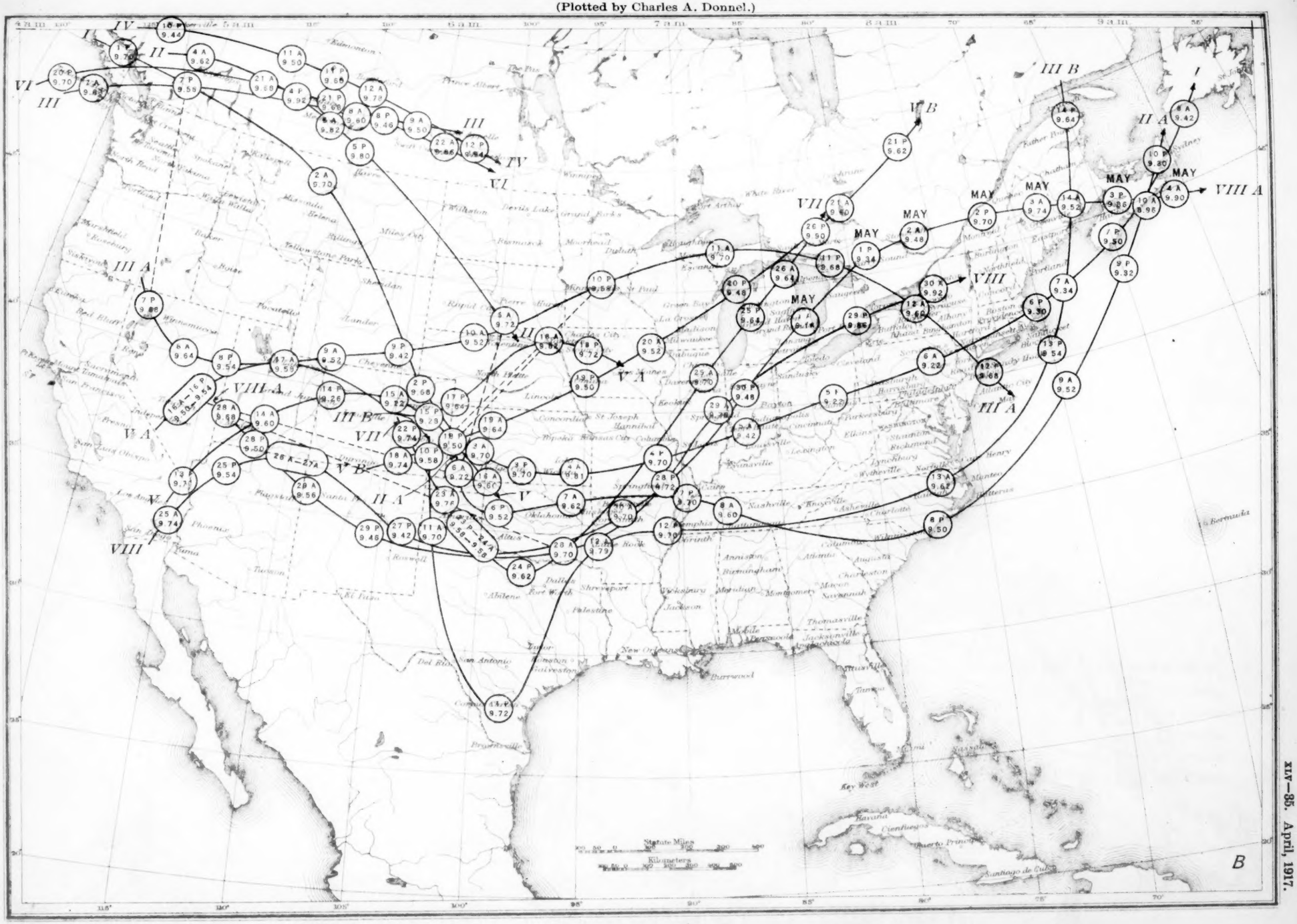
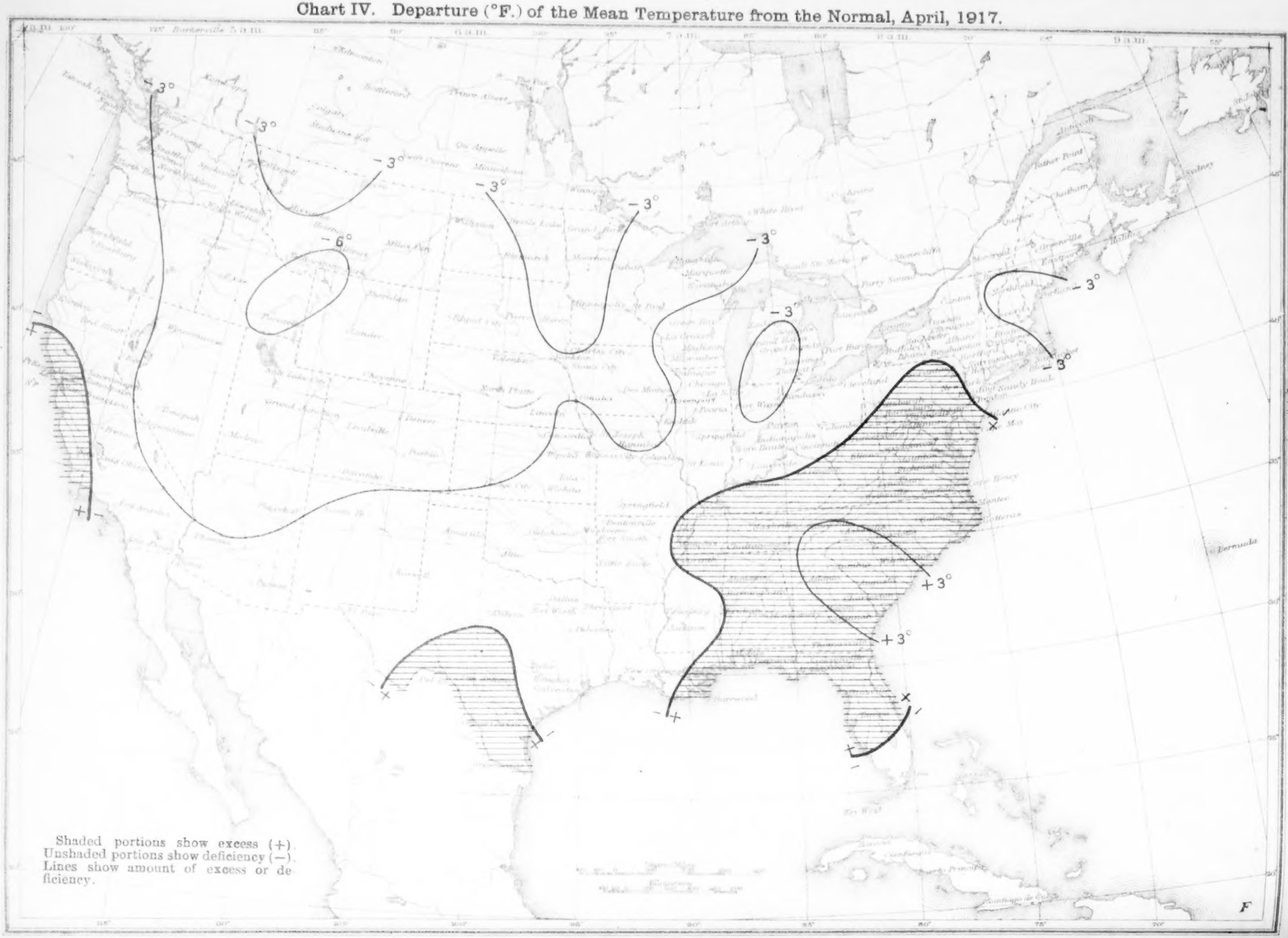


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, April, 1917.



Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart V. Total Precipitation, April, 1917.

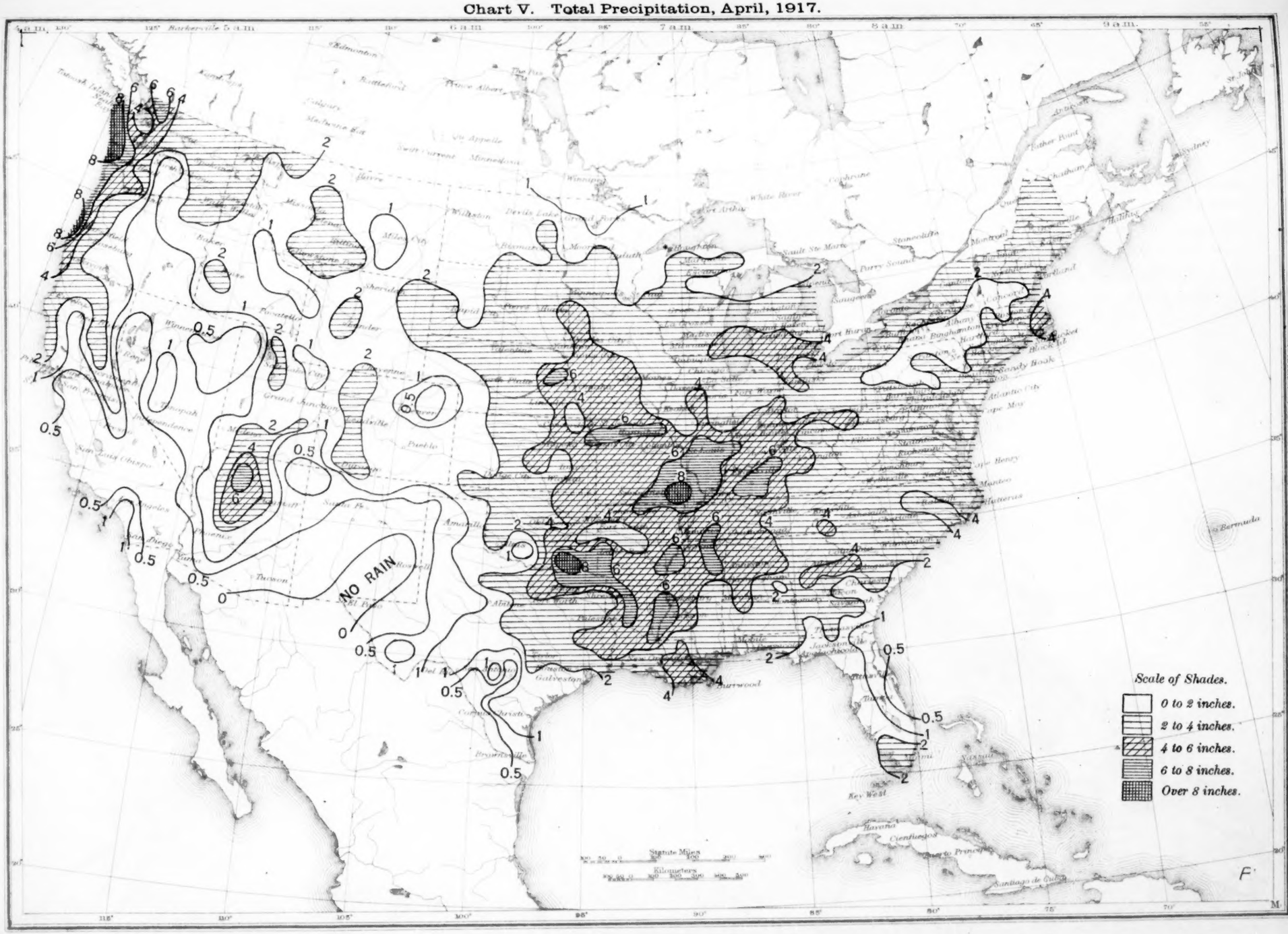


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, April, 1917.

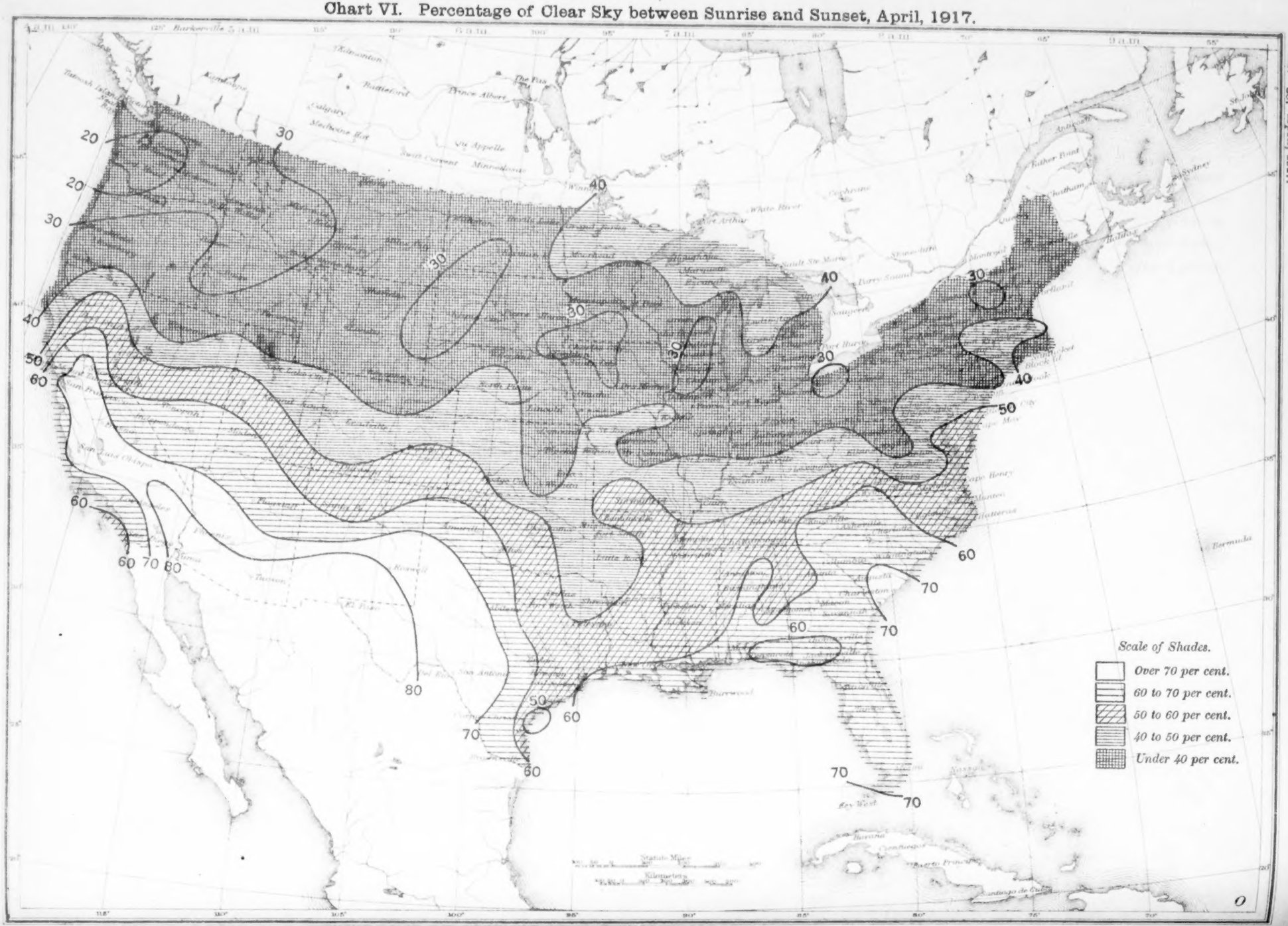


Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, April, 1917.

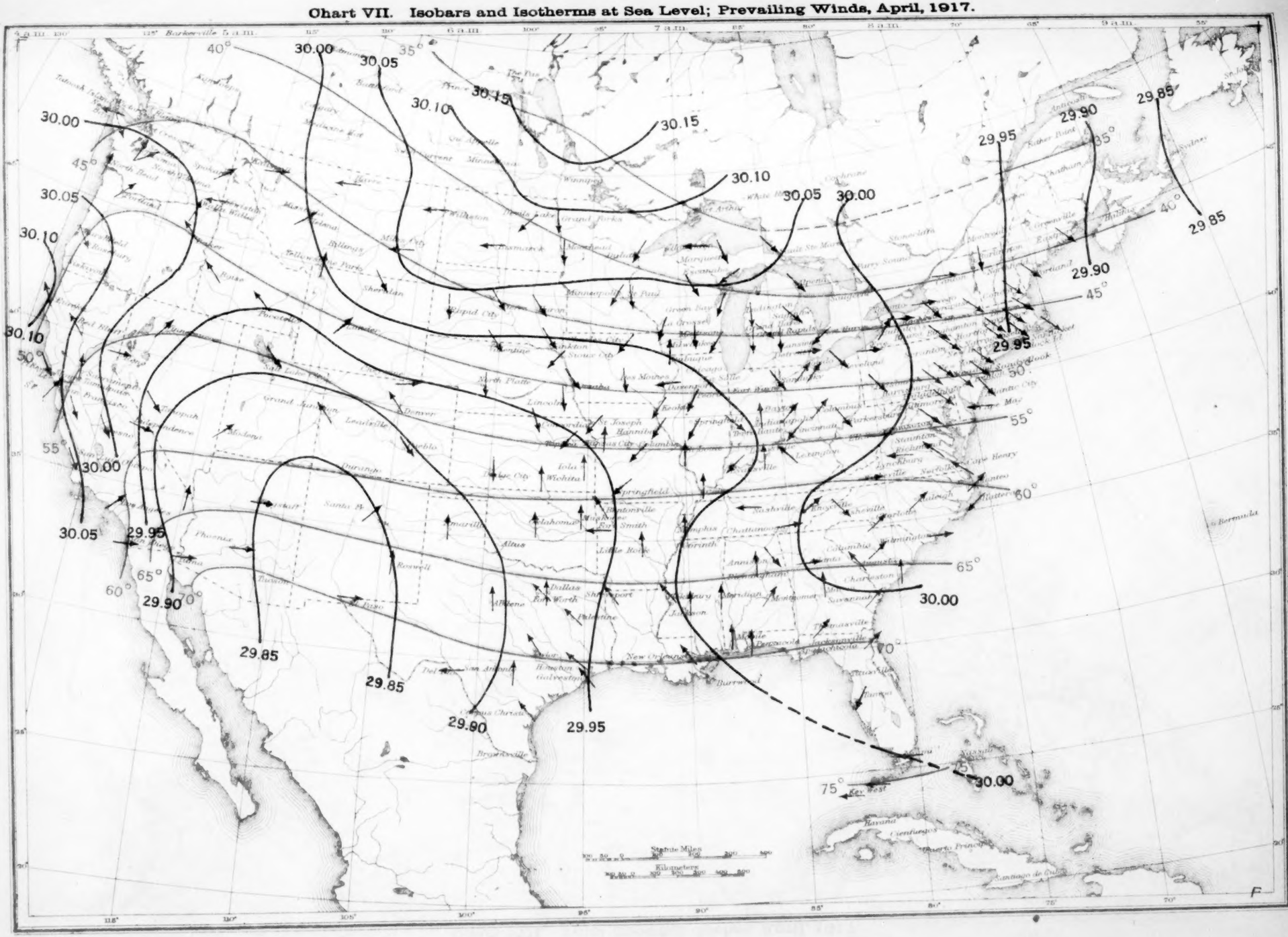


Chart VIII. Total Snowfall, Inches, April, 1917.

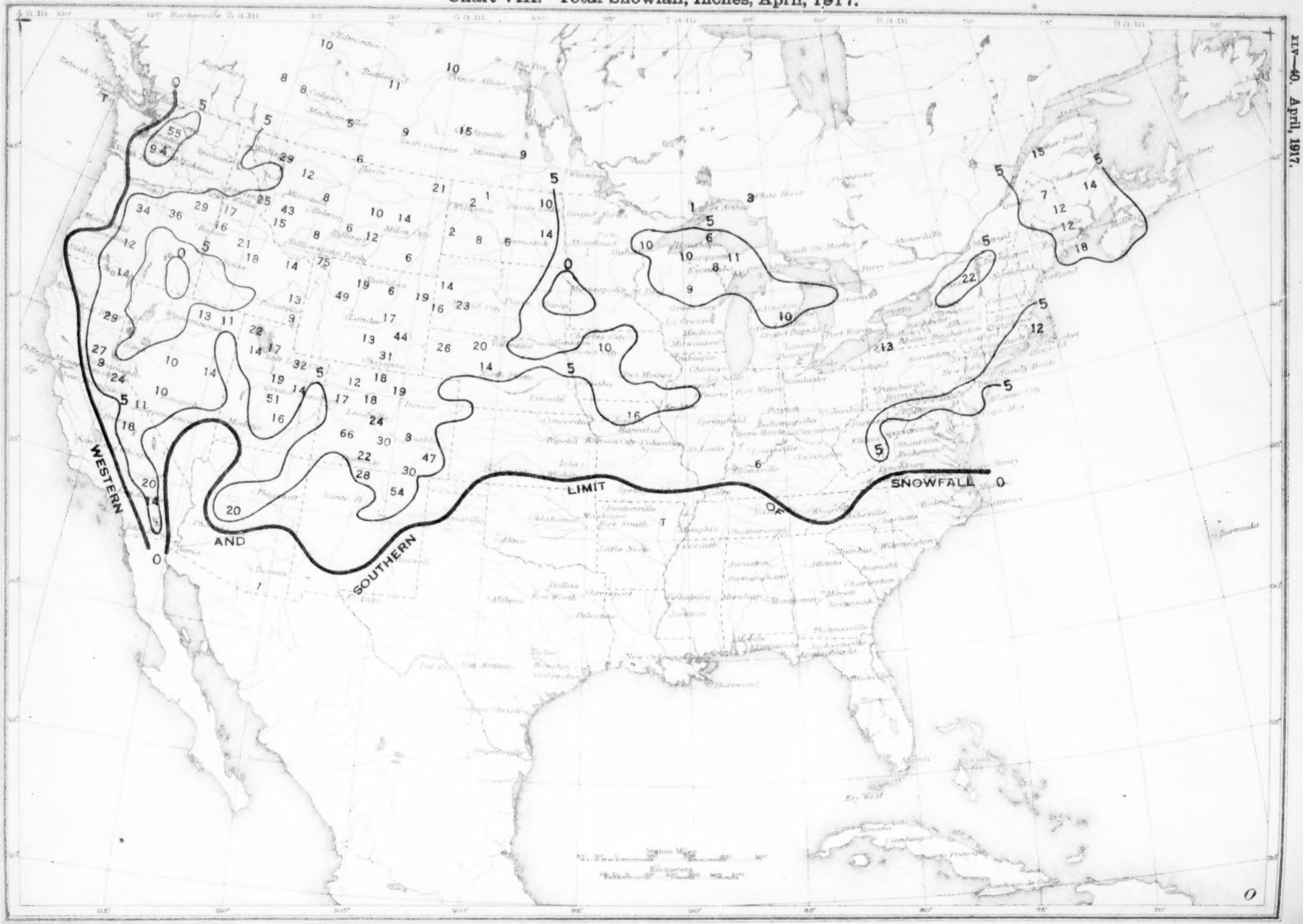


Chart IX. Means of Meteorological Data for North Atlantic Ocean, April, 1916.

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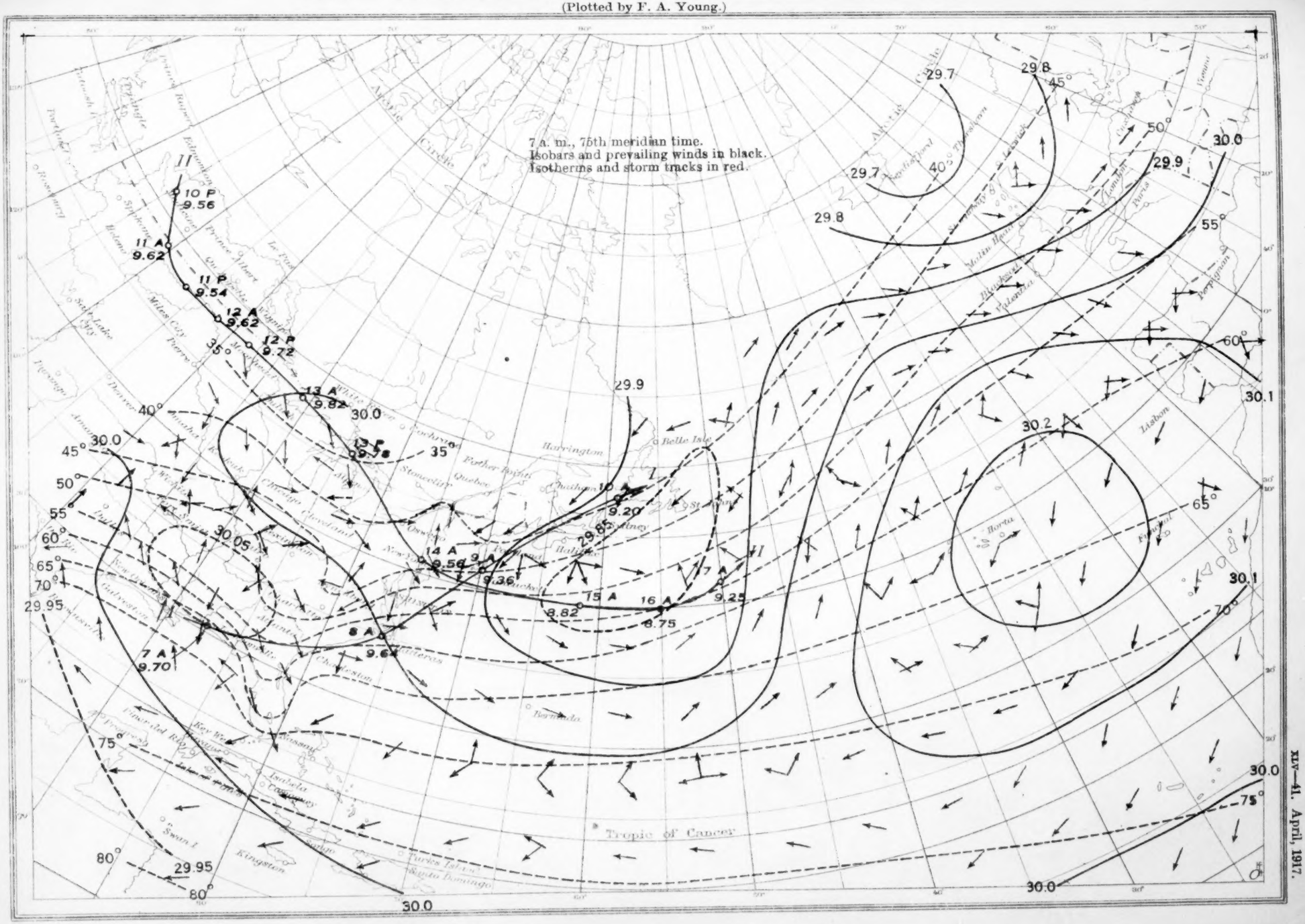
(Plotted by F. A. Young.)